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HgCdTe HIGH RELIABILITY

Final Technical Report

Contract DAAK02-72-C-0113

by

Warren R. Sheese

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May 1972

Prepared For:

US Army Mobility Equipment R & D Center
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Fort Belvoir, Virginia 22060

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D A Project No. PAN 22595708 2191/E554/72

SUMMARY

Ten (10) photoconductive HgCdTe detectors encapsulated in glass evacuated dewars were designed, fabricated, tested, and delivered. Each detector dewar unit was prepared for optimum high temperature storage and vacuum integrity characteristics. The electrical and mechanical performance of each assembly met or exceeded the specifications of Attachment No. 1, Procurement Description entitled "HgCdTe High Reliability," dated 24 August 1971, as modified and attached herewith.

It is anticipated that long-term US Army Night Vision Laboratory evaluation of these units will provide the basis for demonstrating the desired objectives of high performance, high reliability, vacuum integrity, low heat load, and stable high temperature storage characteristics for photoconductive HgCdTe detectors.

Preliminary evaluation of one delivered unit indicates that evacuation bake-out temperatures much higher than the 50°C and 73°C used for this program are feasible. An OPTOELECTRONICS, Inc. recommendation for a small program to optimize elevated temperature evacuation bake-out is included in the Conclusions and Recommendations section.

FOREWORD

This Final Technical Report was prepared by OPTOELECTRONICS, Inc., Petaluma, California, 94952. This report was submitted for Department of the Army approval on 5 May 1972, as called for under Army Contract DAAK02-72-C-0113, "HgCdTe High Reliability," Project No. PAN 22595708 2191/E554/72.

The work on this program was under the direction of the Night Vision Laboratory, US Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia, 22060. The Army Contracting Officer's Representative was Mr. James Gilpin, Code AMSEL-HL-NV-FIR.

This report covers work conducted between 2 November 1971 and 28 April 1972. The following personnel were principal contributors to this program: Mr. L. Roberts, Mr. R. Bell, Mr. W. Sheese, Mr. L. Wenger, and Mr. D. Williams.

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1.0 INTRODUCTION AND SUMMARY

The objective of this program was to design, fabricate, test, and delivery ten (10) single element Mercury Cadmium Telluride (HgCdTe) detectors encapsulated in glass evacuated dewars. These units were to demonstrate high performance and high reliability operation at 77°K in the 8 to 14 micrometer spectral region, and have a low heat load dissipation. The detectors and dewars were also to have characteristics for high temperature storage and vacuum integrity.

Four (4) units were shipped in February 1972, four (4) units in March 1972, and the final two (2) units were shipped in April 1972. All delivered units met or exceeded the performance requirements of the Night Vision Laboratory "Purchase Description (for) HgCdTe High Reliability (Detectors)," Attachment No. 1 to Contract DAAK02-72-C-0113, as modified and attached herewith as Appendix A. The drawing for these ten (10) units and the Evaluation Data are included as Appendix A and Appendix B.

Detector/dewar design and the fabrication history of the detector/dewar assemblies is discussed in Section 2.0 Long-term evaluation of the delivered units is expected to lead to

the development and demonstration of the optimum in vacuum integrity, elevated temperature storage stability, and high sensitivity, for single element HgCdTe detectors.

Beyond the work performed under this program, which involved 50°C and 73°C evacuation bake-out temperatures, developments have occurred which indicate that HgCdTe detector/dewar units of this type would withstand evacuation bake-out temperatures in the vicinity of 90 to 100°C. Evacuation bake-out at a temperature in this vicinity, or at a temperature slightly in excess of 100°C, would be extremely important in providing a more stable, reliable device capable of extended elevated temperature storage.

2.0 HgCdTe DETECTOR/DEWAR FABRICATION

2.1 Detector/Dewar Design

The objective of this program was to design, fabricate, test, and deliver ten (10) HgCdTe Detector/Dewar Assemblies meeting the requirements of the "Purchase Description for HgCdTe High Reliability" dated 24 August 1971 but with the following modification:

Each dewar has a 1/2-inch evacuated tip-off tube rather than the 2 to 3 inch tip-off originally specified.

2.1.1 Detector Element

Each detector element was supplied to OPTOELECTRONICS, Inc. by Mullard, Ltd., London, England. Each element was fabricated to the detector dimensions and substrate layout as required by the Purchase Description.

2.1.2 Window Material

The spectral transmission and other requirements imposed by the performance specifications result in Irtran II being the logical choice for window material. The window dimensions for the completed Irtran II window section are shown in Appendix B on OPTO Drawing SK 10829.

2.1.3 Cold Shield/Aperture Assembly

A cold shield/aperture assembly was designed to meet the field-of-view requirements. This assembly is shown on OPTO Drawing SK 10829.

2.1.4 Dewar

The final dewar design incorporating the elongated pump-out tube and a coolant hold time in compliance with the requirements of the referenced purchase description is shown in OPTO Drawing SK 10829, which is included in Appendix B.

2.1.5 Operating Temperature

The operating temperature for purposes of determining performance characteristics and compliance with performance specifications was 77°K; however, the flask assembly is designed to be operational at other temperatures if liquid coolants other than liquid nitrogen are used in the well.

2.2 Fabrication and Evaluation

The original program schedule called for design, fabrication, test, and delivery of five (5) of the detector/dewar assemblies within seventeen weeks after contract start, or by 29 February 1972. The remaining five (5) units were to be assembled, tested, and delivered within twenty-one weeks from the effective date of contract or by 28 March 1972.

The fabrication and evaluation history of each unit prepared under this program is summarized in the remainder of this section.

2.2.1 Unit 1328-1 through 1328-5

Upon receipt of the first five (5) HgCdTe elements from Mullard, Ltd. in early February each element was given a preliminary test to check for compliance with the performance requirements of the Purchase Description for HgCdTe High Reliability Detectors. Preliminary tests consisted of measurements of resistance, signal and noise for each element together with mechanical and visual inspection.

The preliminary test indicated that all of the elements received exceeded minimum performance specifications.

Final assembly of the completed dewar was then initiated and final evacuation of the first five (5) units was started on 11 February 1972. During the final evacuation period these five (5) units were baked at 50°C for ten (10) days.

On 24 February 1972 the units were removed from the evacuation system and evaluated for performance and dewar hold time at 77°K. These tests indicated that four (4) of the five (5) units exceeded the D* (500,800Hz,1) specification and one (1) unit, S/N 1328-4, had no apparent signal. Further evaluation of unit 1328-4 showed that the element was shorting out when cooled to 77°K.

Evaluation Data on delivered units 1328-1, 1328-2, 1328-3, and 1328-5 appears in Appendix C. The failure of unit 1328-4 is further discussed in section 2.2.3.

2.2.2 Units 1328-6 through 1328-10

These five (5) detector elements were received from Mullard, Ltd. on 28 February 1972 and underwent preliminary testing on 2 March 1972. Preliminary tests indicated that all five (5) elements exceeded the minimum performance specifications.

Final evacuation of these five (5) units was started on 5 March 1972. During the final evaucation period these units were baked at 50°C for ten (10) days.

On 20 March 1972 these units were removed from the evacuation system and tested for performance and for dewar hold time at 77°K. All units exceeded specification; however, unit 1328-6 was not shipped because a loose piece of excess solder from the seal ring was observed inside the dewar.

Evaluation data on delivered units 1328-7, 1328-8, and 1328-9, and 1328-10 appears in Appendix C. Further discussion of the failure of unit 1328-6 is continued in section 2.2.4.

2.2.3 Unit 1328-4

After opening this unit a Quality Assurance visual inspection revealed the cold shield/aperture had shifted during evacuation and was shorting the element leads. This failure was corrected. A longer setup time for the adhesive used to hold the cold shield/aperture will be used on future assemblies to avoid this type of failure.

2.2.4 Unit 1328-6

Quality Assurance inspection revealed a loose piece of solder present inside the dewar. Although the unit met performance specifications, it would be unreliable for system use.

Unit 1328-6 was opened at the evacuation tip off and the loose solder removed. It is believed that any future problems with loose excess solder have been eliminated by more accurately controlling the amount of solder used in pre-tinning the package seal rings.

2.2.5 Units 1328-4 and 1328-6

Unit 1328-4 was reassembled on 6 April 1972. Repaired units 1328-4 and 1328-6 were placed on the evacuation system on 7 April 1972 and baked for ten (10) days at 50°C.

On 13 April 1972, Mr. James Gilpin, Project Engineer, Night Vision Laboratory, contacted OPTOELECTRONICS, Inc. by telephone and requested the bake-out temperatures be increased on one of the two units still under evacuation. Since unit 1328-4 had been completely disassembled and reassembled, it was felt that the increased bake-out temperature would be most beneficial to this unit. Therefore, on 20 April 1972, before removing these two (2) units from the evacuation system, unit 1328-4 was baked at 73°C for an additional eight (8) hours.

On 21 April 1972 both units were removed from the evacuation pump and tested. Each unit exceeded the minimum performance requirements of the Purchase Description.

Evaluation data on delivered units 1328-4 and 1328-6 appears in Appendix C.

3.0 CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions

Fabrication of the required ten (10) detector/dewar assemblies posed little difficulty. The minor assembly problems encountered in two units have led to improved fabrication procedures which should prevent the recurrence of these problems in any future units.

No difficulty was encountered in meeting the performance requirements of this program.

3.2 Recommended Evacuation Bake-Out Optimization Program

The work performed under this program involved an evacuation bake-out temperature of 50°C for 10 days, except one unit was baked-out for an additional 8 hours at 73°C. Such low evacuation bake-out temperatures in the range of 50°C are typical in the industry and are used because of concern that elevated temperatures might damage the HgCdTe element.

After delivery of these OPTOELECTRONICS, Inc. units to NVL, one detector was baked at 100°C, which resulted in vacuum degradation, but did not appear to adversely affect the sensitivity of the HgCdTe element. Under another program, several OPTOELECTRONICS, Inc. HgCdTe detector units have been evacuation-baked at temperatures of 90°C, with no apparent damage to the detector element.

An evacuation bake-out procedure using temperatures in the 90-100°C range would provide significantly improved vacuum integrity, and insure a much longer field life for HgCdTe detector units. If the bake-out temperature could be raised to a temperature as high as 105 to 110°C, it would be even better as this would assure that all parts of the unit would reach a temperature higher than the boiling point of water and help eliminate any residual absorbed water vapor on interior surfaces.

In view of the successful performance of OPTOELECTRONICS, Inc. HgCdTe detectors after exposure to temperatures in the 75 to 100°C temperature range, and in view of the immediate need for improved reliability, vacuum integrity, and high temperature storage characteristics for HgCdTe detectors, OPTOELECTRONICS, Inc. recommends the following program to develop and demonstrate an optimum evacuation bake-out schedule for OPTOELECTRONICS, Inc. HgCdTe detectors.

PROPOSED PROGRAM

It is recommended that fifteen (15) HgCdTe detectors be fabricated to the same design employed for the present program. All fifteen units would be fabricated, assembled, and after passing preliminary evaluation, would be mounted on vacuum stations. All fifteen units would be evacuation baked for a period of about ten (10) days at 75°C. At the end of this period, each detector would be evaluated in situ

(on the vacuum pump) to determine performance characteristics. It is anticipated that all fifteen (15) units would meet all performance requirements of the present program.

After this first evaluation, three (3) units would be tipped-off, re-tested, and held as 75°C control units for the remainder of the program.

The remaining 12 units would be evacuation baked for an additional period of two (2) days at 80°C, after which each detector would again be evaluated in situ to determine if performance characteristics were being maintained. After this evaluation an additional two units would be tipped-off, re-tested, and held as 80°C control units for the remainder of the program.

The above procedure of repeating the evacuation bake-out for two (2) days at a temperature 50°C higher than the previous bake-out, testing all units and tipping off an additional two units would also be performed at 85°C, 90°C, 95°C, 100°C, and 105°C.

It is anticipated that this would result in establishing an optimum evacuation bake-out temperature somewhere between 80°C and 105°C. Any units which failed for any reason at any temperature would be thoroughly evaluated and the cause of failure determined.

OPTOELECTRONICS, Inc. recommends the above program as a straightforward and effective way of establishing an improved evacuation bake-out procedure for HgCdTe detectors. This procedure will assure a more reliable HgCdTe unit for field use, with improved vacuum integrity, and a longer life under either normal or elevated temperature storage conditions.

APPENDIX A

U.S. ARMY ELECTRONICS COMMAND
Night Vision Laboratory
Fort Belvoir, Virginia

24 August 71
Modified

PROCUREMENT DESCRIPTION
For
"HgCdTe High Reliability"

1.0 Scope. This Procurement Description covers the fabrication and test of ten (10) single element Mercury Cadmium Telluride (HgCdTe) detectors encapsulated in glass evacuated dewars.

1.1 Objective. The objective of this contract is to obtain high performance and highly reliable single element HgCdTe detectors operating in the 8 to 14 micrometer spectral region and having a low heat load dissipation. The detectors and dewars shall have characteristics for high temperature storage and vacuum integrity.

1.2 Description. The detector elements shall be fabricated from Mercury Cadmium Telluride. Each detector element shall be mounted in an evacuated glass dewar suitable for open cycle cooling with liquid nitrogen.

2.0 Applicable Documents. "Standard Procedure for Testing Infrared Detectors and Describing their Performance" by R. C. Jones, D. Goodwin, and G. Pullan dated 12 September 1960, published by the Office of the Director of Defense Research and Engineering.

3.0 Requirements.

3.1 Material and Workmanship. All materials and components not definitely specified herein and required by this Procurement Description shall be of the best quality normally used for good commercial practice in equipment intended for rugged use. Materials and components shall be free from defects and imperfections that affect the serviceability of the finished product. Workmanship shall be of the highest quality throughout and in accordance with the best commercial practice for this type of equipment. See paragraph 4 for test and inspections to assure compliance.

3.2 Detector Parameters.

3.2.1 Detector Material. Each detector shall be fabricated of Mercury Cadmium Telluride (HgCdTe) to be operated at 77°K.

3.2.2 Detector Size. The detector shall be a 0.003X0.003 inch square element. The sensitive area is defined as the

50% voltage line response of the elements. This value shall be used as the sensitive area in computing detector performance.

3.2.3 Performance. Each detector shall have a peak D* (λ,800 Hz, 1) greater than or equal to 2.0×10^{10} cm $Hz^{1/2}$ $watt^{-1}$ when operating at 77°K.

3.2.4 Spectral Response. Each detector shall have its peak wavelength response between 10.5 micrometers and 12.5 micrometers and maximum response down to 8 micrometers.

3.2.5 Power Dissipation. The power dissipation of each detector when operating in conformance with paragraph 3.2.3 shall be 1.5mw or less.

3.3 Dewar Parameters.

3.3.1 Dewar Type. Dewars shall be made primarily from glass, permanently evacuated, and constructed so as to restrict the field of view to 60°. Each dewar shall have an evacuated tip-off tube suitable for fracture, repump and reseal.

3.3.2 Vacuum Life. The dewar will be so fabricated as to maintain a vacuum sufficient to prevent the IR window from

frosting when the detector is cooled to 77°K and the ambient is 30°C with 50% relative humidity. The minimum vacuum life shall be 12 months, with a design goal of 24 months.

4.0 Quality Assurance Provisions.

4.1 Detector Test Conditions. The general test provisions shall be in accordance with the "Standard Procedure for Testing Infrared Detectors and Describing their Performance".

4.2 Measured Data. The manufacturer shall make the following measurements on each detector and furnish the data as required on the DD Form 1423 and associated DD Forms 1664. In each case, the effective rms irradiance at the detector will be noted.

a. Spectral response
b. Measured rms signal voltage
c. Measured rms noise voltage and bandwidth
d. D* (500, 800 Hz, 1)
e. D* (λ peak, 800 Hz, 1)
f. Noise as a function of frequency from 50 Hz to 20 KHz
g. Detector resistance
h. Responsivity
i. Detector surface contour plot

4.3 Peak Temperature. The data shall include the highest

temperature to which the detector was exposed during manufacture and the length of time of exposure at this temperature.

4.4 Failure Rate. The Contractor shall report on failures during all stages of device preparation. This information shall include:

a. Known and correctable sources of failure with possible solutions;

b. Known and uncorrectable sources of failure; and

c. Failure from unknown sources, with, where possible, hypotheses on causes.

The approximate percentage of failure due to each source shall be tabulated.

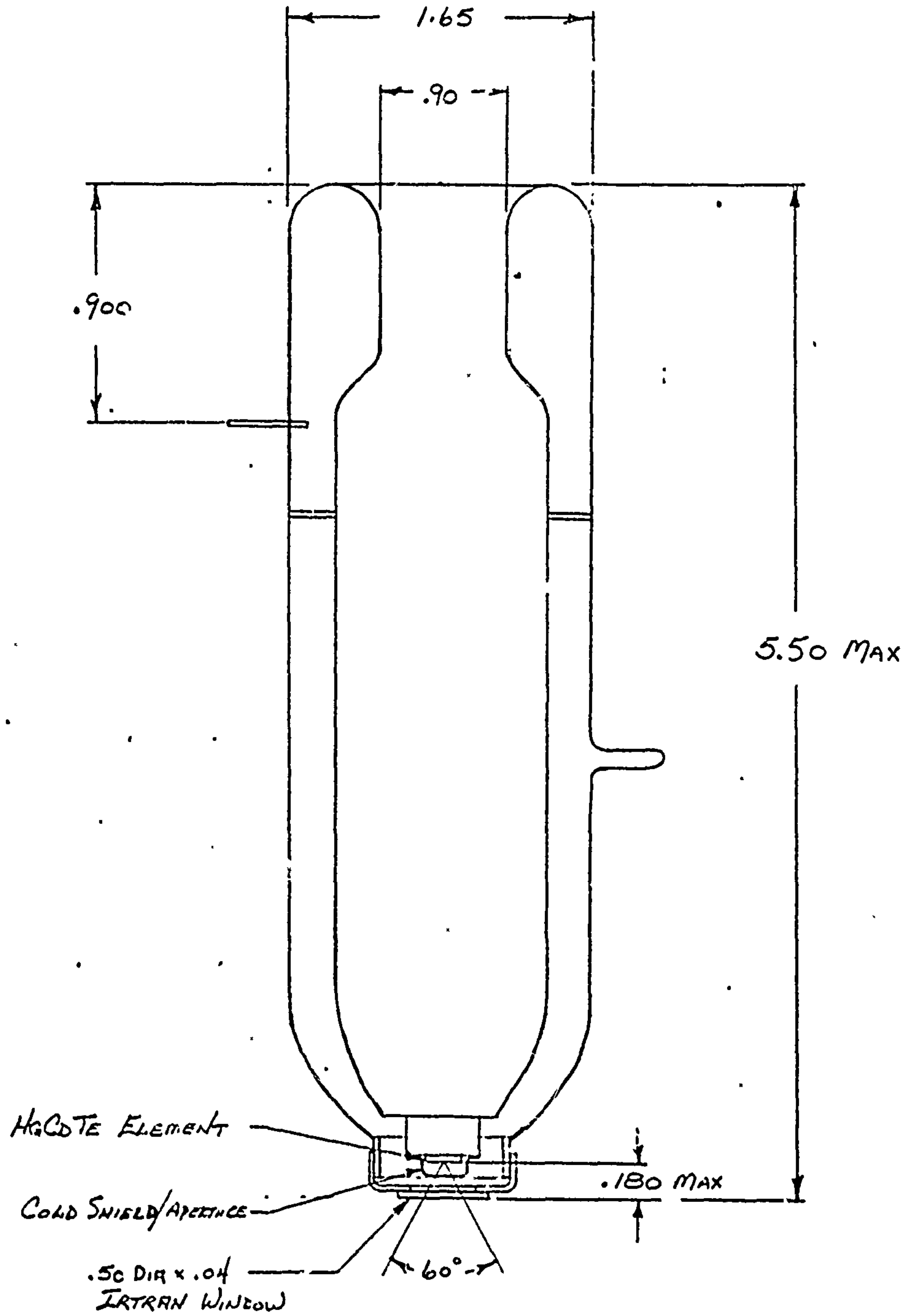
5.0 Preparation for Delivery. The detector package with data required shall be packaged in accordance with good commercial practice for shipping. This package shall be marked in accordance with MIL STD 120 at the direction of the Contracting Officer.

APPENDIX B

DRAWING

Only one drawing was required for fabrication of the HgCdTe detector/dewar assemblies described herein. This drawing is referenced in the body of this report, and is included in this Appendix.

1. OPTO Drawing SK10829, HgCdTe End View Detector/Dewar Unit



PROJECT # 1328	W/O #		TOL. .00 ±.015	TITLE END VIEW DEWAR
MATERIAL 7052 GLASS [illegible] AND IRTRAN II			.000 .010	OPTOELECTRONICS, INC.
DESIGNER [illegible]	DATE [illegible]	APPROVED		SK 10529

APPENDIX C

Evaluation Data on Delivered Detector/Dewar Assemblies

Final acceptance test data on electrical performance parameters for the ten (10) units delivered under this program is contained in this Appendix. Acceptance tests were performed at a detector operating temperature of 77°K for all ten (10) units. The results of that evaluation are reported herein.

OPTOELECTRONICS, INC.
1309 Dynamic Street - Petaluma, Ca. 94952

DATA SHEET

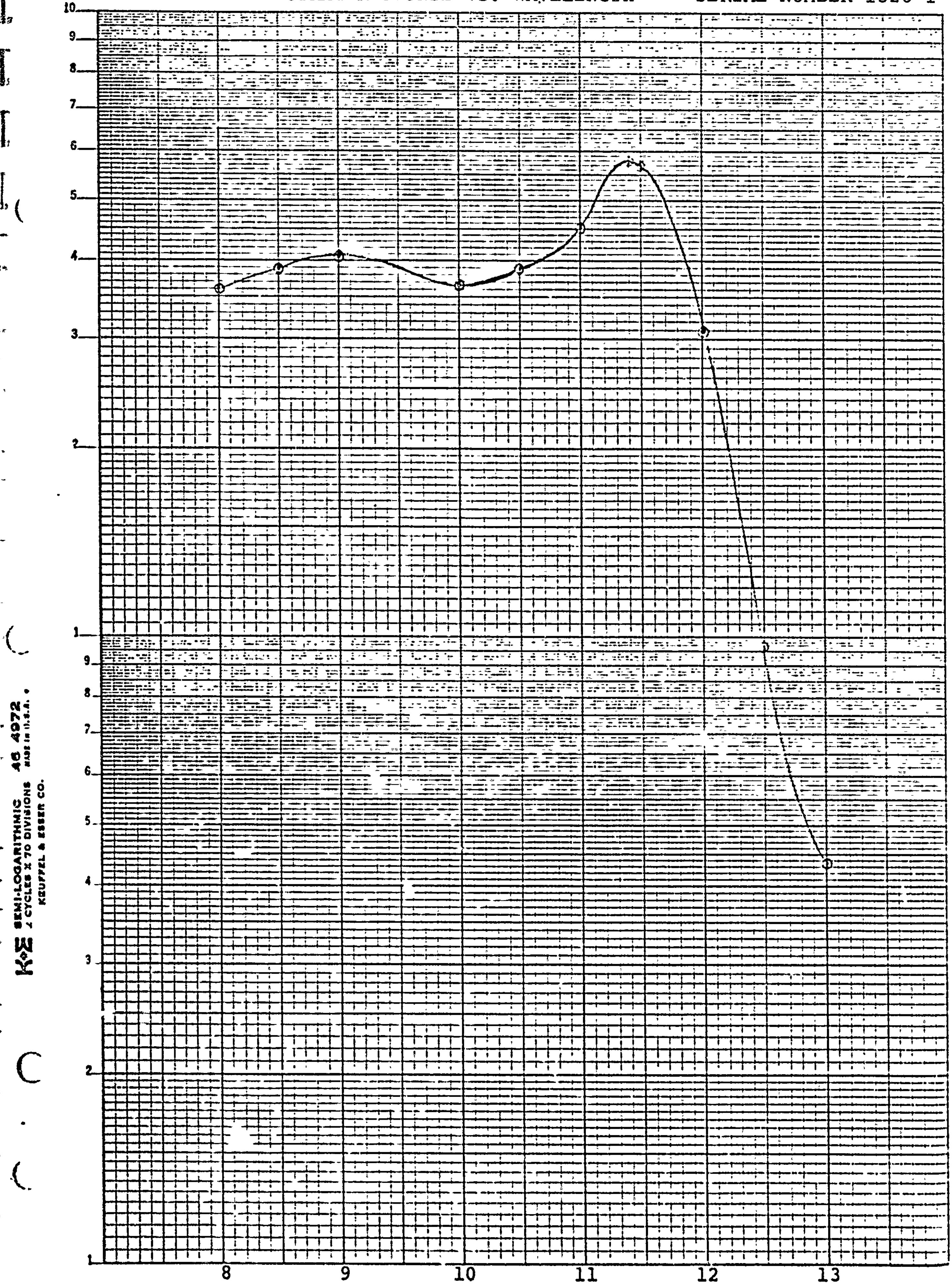
PROJECT NO. 1328
DEVICE NO. 215-UNC
DATE 2/28/72
MATERIAL HCT
TESTER W.R.S.
FLUX DENSITY 1.81064×10^{-5} w/cm^2
CHOPPING FREQ. 1K Hz
SERIAL NUMBER 1328-1

BLACKBODY TEMP. 500°K
F.O.V. 60°
AREA 70µm x 70µm
OPERATING TEMP. 77°K
LOAD RESISTOR 1KΩ
BANDPASS 10 Hz
SYSTEM GAIN 8.5×10^5

ELE. No.	E_{oc} (mv)	I_{det} (ma)	Responsivity λ V/W	R_c Amb	R_c Cold	Detector Bias (V)	V Signal (ma)	V Noise (ma)	S/N	D* BB (cm Hz^{½} watt^{-1})	D* λ (cm Hz^{½} watt^{-1})
1		0		26Ω	36Ω			1.5			
		.5	1006				380	1.8	211	5.27×10^9	1.05×10^{10}
		1.0	2120				800	2.4	333	8.32×10^9	1.66×10^{10}
		1.5	2916				1100	3.0	366	9.14×10^9	1.83×10^{10}
		2.0	4242				1600	3.6	444	1.10×10^{10}	2.22×10^{10}
		2.5	5170				1950	4.2	464	1.16×10^{10}	2.32×10^{10}
		3.0	6222				2350	5.0	470	1.17×10^{10}	2.35×10^{10}
		4.0	7690				2900	7.0	414	1.03×10^{10}	2.06×10^{10}
		5.0	9016				3400	9.0	377	9.42×10^9	1.89×10^{10}
		6.0	10342				3900	10.0	390	9.7×10^9	1.95×10^{10}

Dewar Dwell Time @ 77°K 8.5 hrs.

SPECTRAL RESPONSE vs. WAVELENGTH SERIAL NUMBER 1328-1



OPTOELECTRONICS, INC.
1309 Dynamic Street - Petaluma, Ca. 94952

DATA SHEET

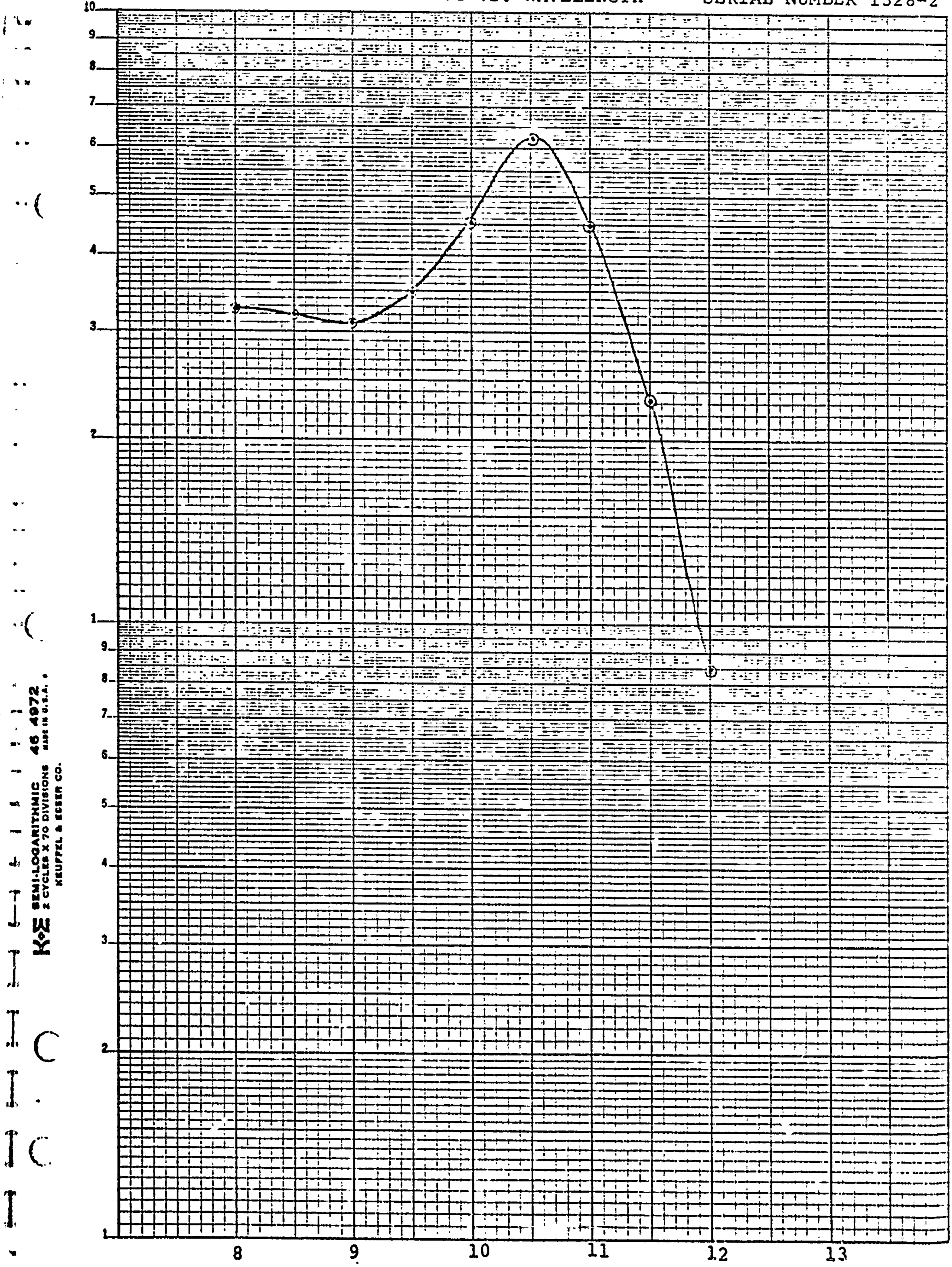
PROJECT NO. 1328
DEVICE NO. 202-UNC
DATE 2/28/72
MATERIAL HCT
TESTER W.R.S.
FLUX DENSITY 1.81064×10^{-5} w/cm^2
CHOPPING FREQ. 1K Hz
SERIAL NUMBER 1328-2

BLACKBODY TEMP. 500°K
F.O.V. 60°
AREA 70um x 70um
OPERATING TEMP. 77°K
LOAD RESISTOR 1KΩ
BANDPASS 10 Hz
SYSTEM GAIN 8.5×10^5

ELE. No.	E_{oc} (mv)	I_{det} (ma)	Responsivity λ V/W	R_c Amb	R_c Cold	Detector Bias (V)	V Signal (ma)	V Noise (ma')	S/N	D* BB (cm Hz$^{1/2}$ watt^{-1})	D* λ (cm Hz$^{1/2}$ watt^{-1})
1		0		22Ω	35Ω						
		.5	1298				490	2.4	204	5.09×10^9	1.02×10^{10}
		1.0	2916				1100	2.6	423	1.06×10^{10}	2.11×10^{10}
		1.5	4640				1750	3.4	514	1.28×10^{10}	2.57×10^{10}
		2.0	6198				2300	4.0	575	1.43×10^{10}	2.87×10^{10}
		2.5	7690				2900	5.5	527	1.32×10^{10}	2.63×10^{10}
		3.0	8016				3400	7.0	485	1.21×10^{10}	2.42×10^{10}
		4.0	12066				4550	8.5	535	1.34×10^{10}	2.67×10^{10}
		5.0	14850				5600	10.0	560	1.40×10^{10}	2.79×10^{10}
		6.0	17238				6500	12.0	541	1.35×10^{10}	2.70×10^{10}

Dewar Dwell Time @ 77°K 8.5 hrs.

SPECTRAL RESPONSE vs. WAVELENGTH SERIAL NUMBER 1328-2



WAVELENGTH (MICRONS)

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OPTOELECTRONICS, INC.
1309 Dynamic Street - Petaluma, Ca. 94952

DATA SHEET

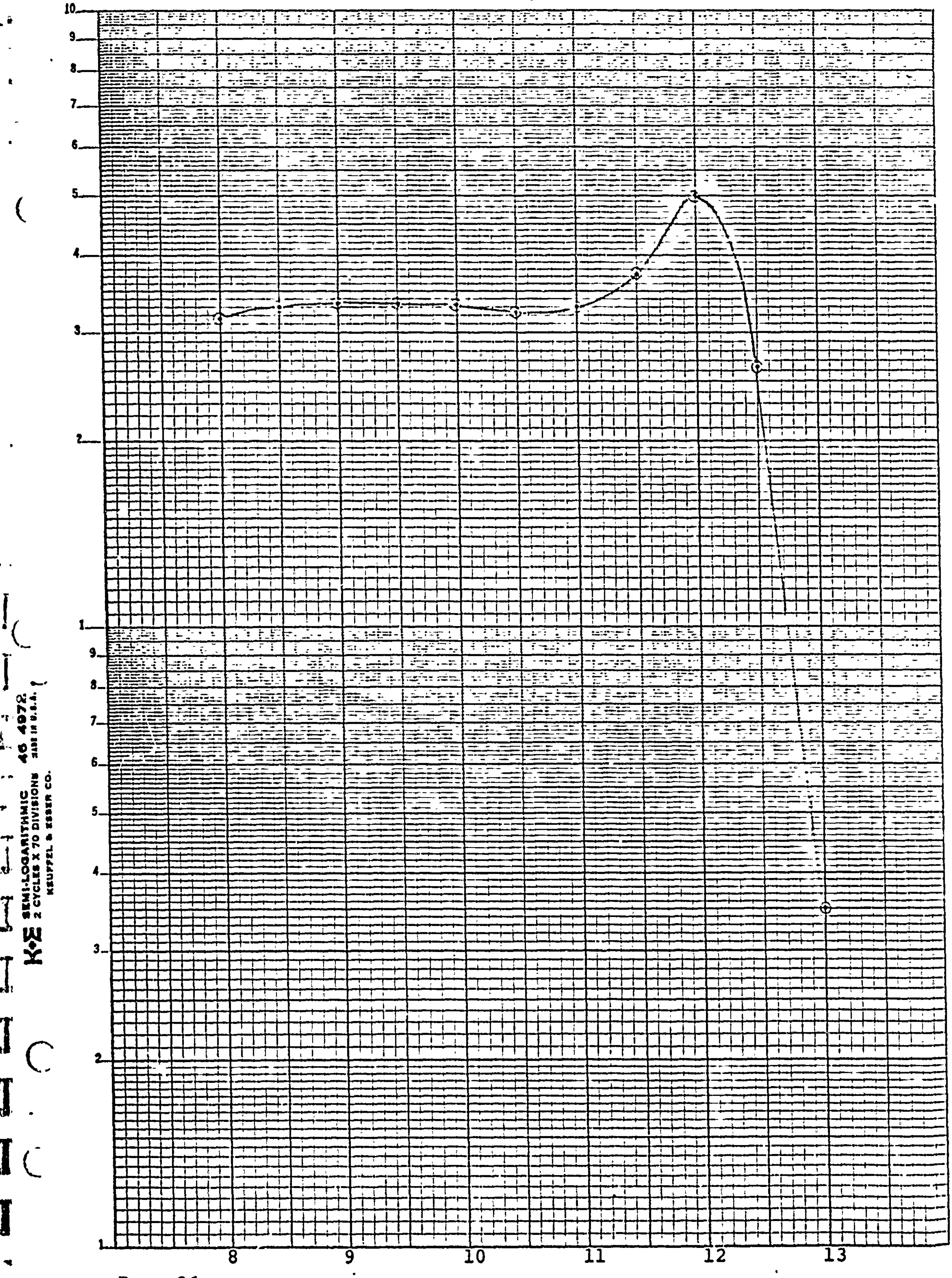
PROJECT NO. 1328
DEVICE NO. 217-UNC
DATE 2/28/72
MATERIAL HCT
TESTER W.R.S.
FLUX DENSITY 1.81064×10^{-5} w/cm^2
CHOPPING FREQ. 1K Hz
SERIAL NUMBER 1328-3

BLACKBODY TEMP. 500°K
F.O.V. 60°
AREA 70μm x 70μm
OPERATING TEMP. 77°K
LOAD RESISTOR 1KΩ
BANDPASS 10 Hz
SYSTEM GAIN 8.5×10^5

ELE. No.	E_{oc} (mv)	I_{det} (ma)	Responsivity λ V/W	R_c Amb	R_c Cold	Detector Bias (V)	V Signal (ma)	V Noise (ma)	S/N	(cm Hz^{½} watt^{-1}) D* BB	D* λ
1		0		22Ω	38Ω			2.0			
		.5									
		1.0	1326				500	1.8	277	6.93×10^9	1.39×10^{10}
		1.5	2014				760	2.0	380	9.48×10^9	1.80×10^{10}
		2.0	2652				1000	2.6	384	9.60×10^9	1.92×10^{10}
		2.5	3314				1250	3.0	416	1.04×10^{10}	2.08×10^{10}
		3.0	3910				1475	3.4	433	1.08×10^{10}	2.16×10^{10}
		4.0	5304				2000	4.0	500	1.25×10^{10}	2.50×10^{10}
		5.0	6630				2500	4.8	625	1.56×10^{10}	3.12×10^{10}
		6.0	7822				2950	6.0	491	1.23×10^{10}	2.45×10^{10}
		7.0	8750				3300	7.0	471	1.18×10^{10}	2.35×10^{10}

Dewar Dwell Time @ 77°K 8.5 hrs.

SPECTRAL RESPONSE vs. WAVELENGTH SERIAL NUMBER 1328-3



WAVELENGTH (MICRONS)

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OPTOELECTRONICS, INC.
1309 Dynamic Street - Petaluma, Ca. 94952

DATA SHEET

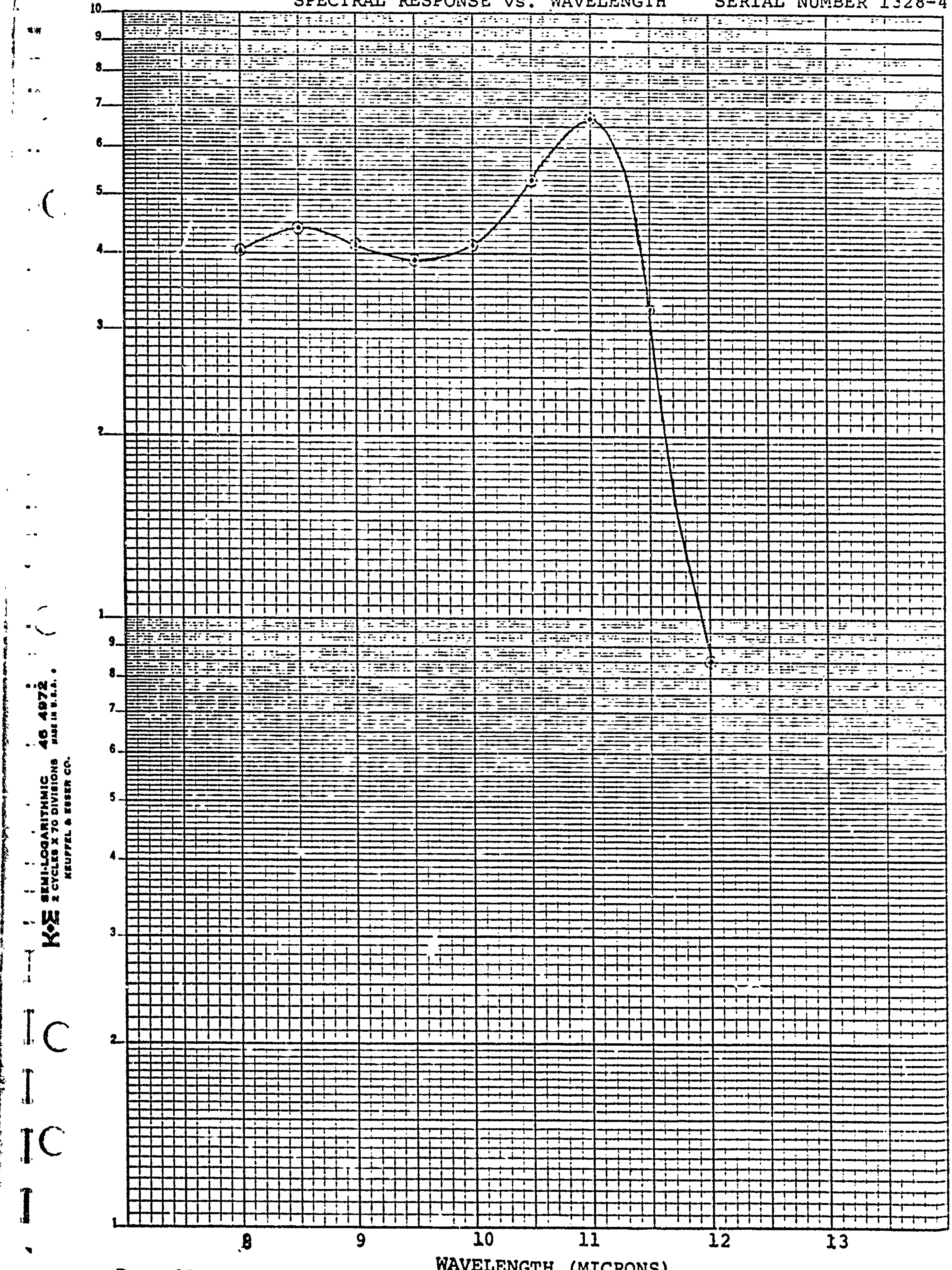
PROJECT NO. 1328
DEVICE NO. 224-UNC
DATE 4/17/72
MATERIAL HCT
TESTER W.R.S.
FLUX DENSITY 1.81064 x 10^{-5} w/cm^2
CHOPPING FREQ. 1K Hz
SERIAL NUMBER 1328-4

BLACKBODY TEMP. 500°K
F.O.V. 60°
AREA 70μm x 70μm
OPERATING TEMP. 77°K
LOAD RESISTOR 1KΩ
BANDPASS 10 Hz
SYSTEM GAIN 8.5 x 10^5

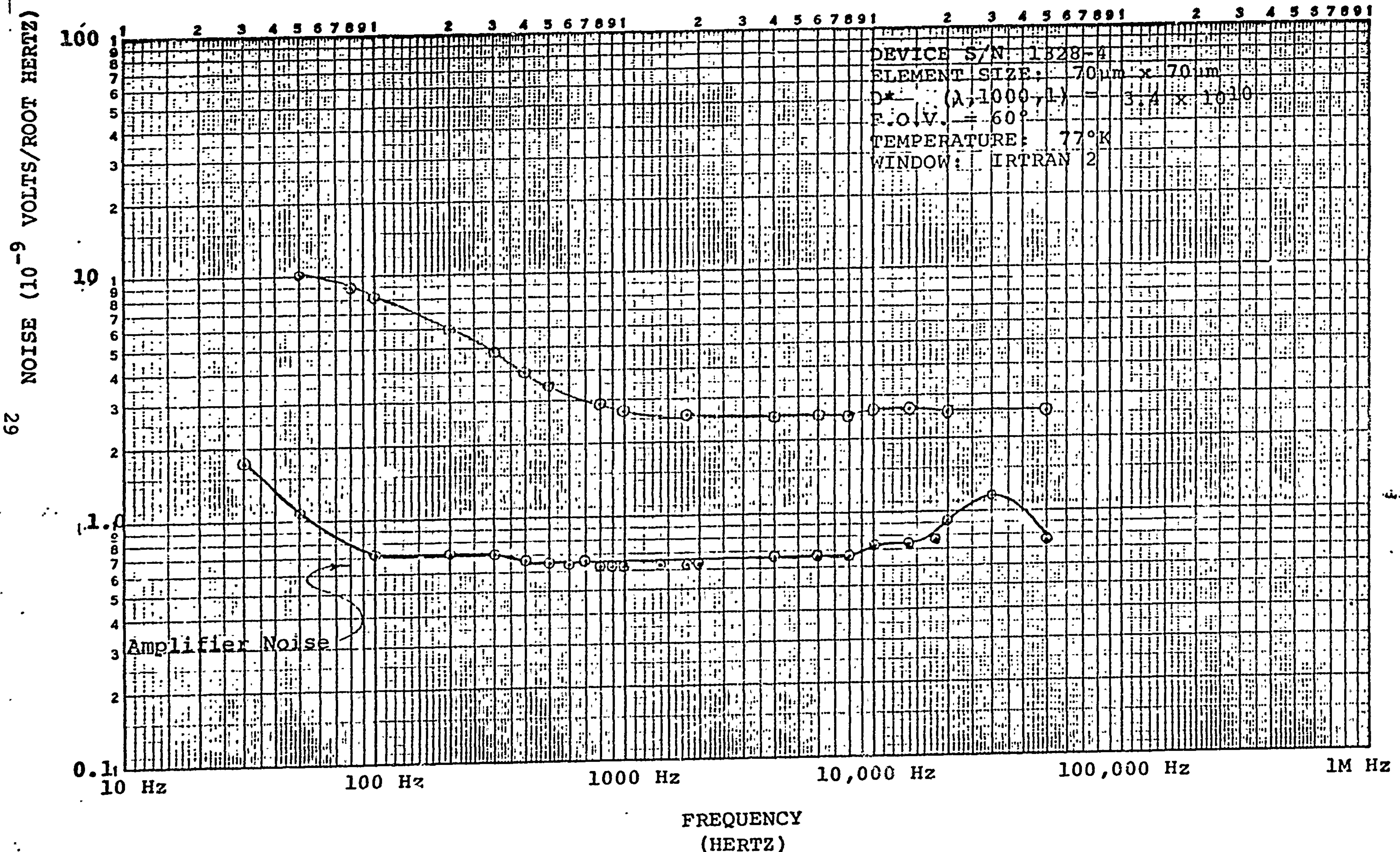
ELE. No.	E_{oc} (mv)	I_{det} (ma)	Responsivity λ (V/W)	R_c Amb	R_c Cold	Detector Bias (V)	V Signal (mv)	V Noise (mv)	S/N	D* BB (cm Hz$^{1/2}$ watt^{-1})	D* λ (cm Hz$^{1/2}$ watt^{-1})
Single		0	—	26Ω	31Ω			1.8			
		0.5	1670				630	2.0	315	7.86 x 10^9	1.57 x 10^{10}
		1.0	4376				1650	3.0	550	1.37 x 10^{10}	2.74 x 10^{10}
		1.5	6232				2350	4.0	588	1.47 x 10^{10}	2.93 x 10^{10}
		2.0	7956				3000	5.0	600	1.50 x 10^{10}	3.00 x 10^{10}
		2.5	9282				3500	5.5	636	1.59 x 10^{10}	3.18 x 10^{10}
		3.0	10872				4100	6.0	683	1.70 x 10^{10}	3.40 x 10^{10}
		4.0	12996				4900	8.0	613	1.53 x 10^{10}	3.06 x 10^{10}
		5.0	14586				5500	10.0	550	1.37 x 10^{10}	2.74 x 10^{10}

Dewar Dwell Time @ 77°K 8.5 hrs.

SPECTRAL RESPONSE vs. WAVELENGTH SERIAL NUMBER 1328-4

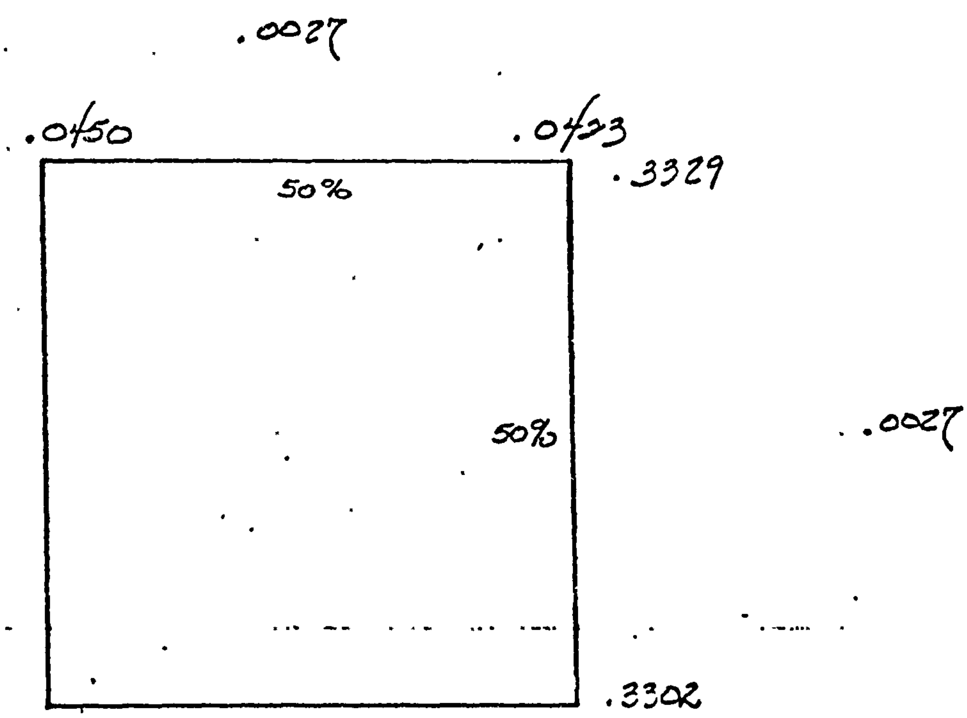


OPTO/MULLARD CMT NOISE SPECTRUM
FINAL PACKAGE



OPTOELECTRONICS, INC.

SK



PROJECT # 1328	W/O #	TOL. .00 ±.015	TITLE Spot Contour
MATERIAL HCT		.000 ±.010	OPTOELECTRONICS, INC.
DESIGNER	DATE 4/26	APPROVED [illegible]	SK 1328-4

OPTOELECTRONICS, INC.
1309 Dynamic Street - Petaluma, Ca. 94952

DATA SHEET

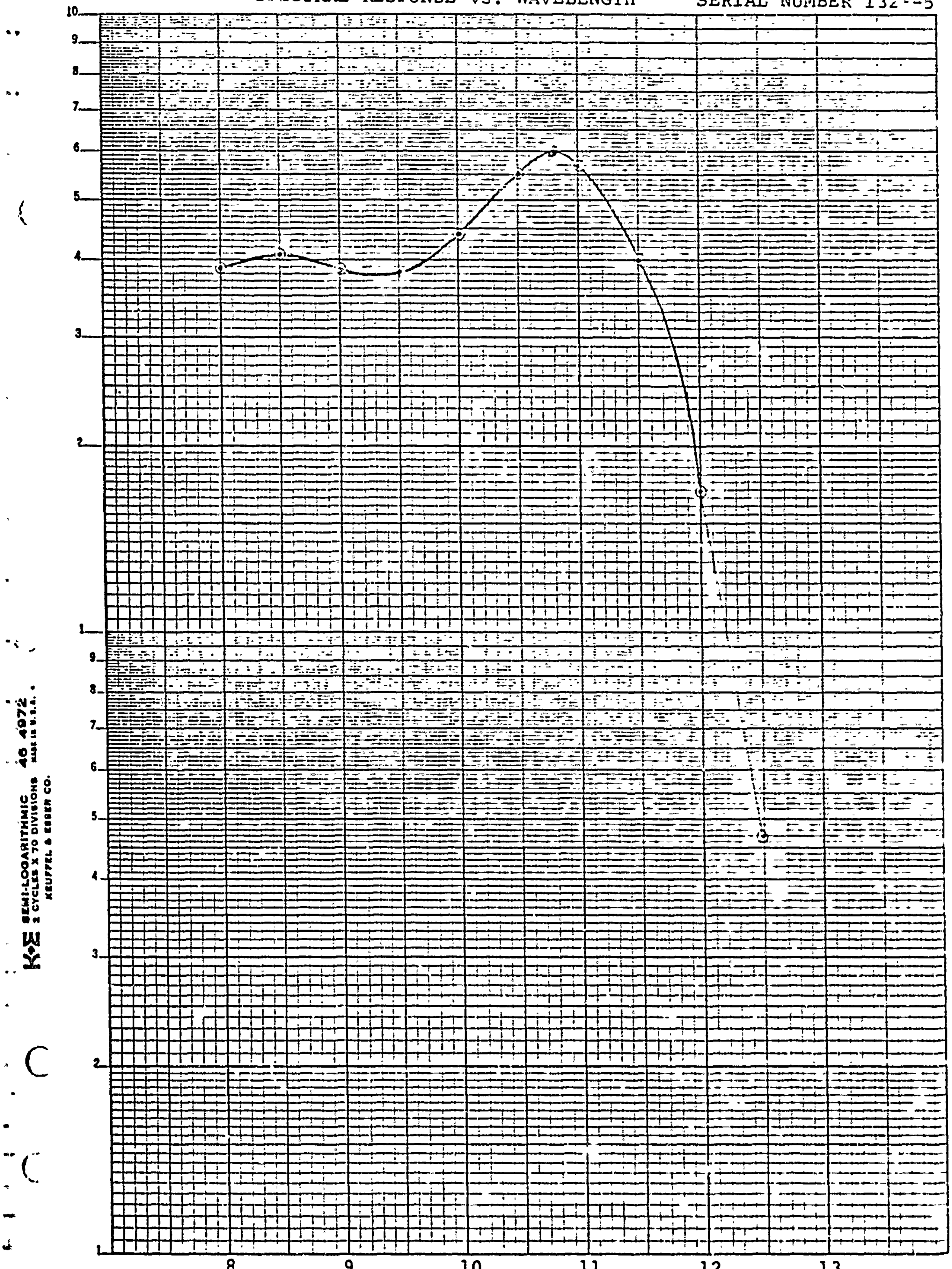
PROJECT NO. 1328
DEVICE NO. 213 UNC
DATE 2/28/72
MATERIAL HCT
TESTER W.R.S.
FLUX DENSITY 1.81064×10^{-5} w/cm^2
CHOPPING FREQ. 1K Hz
SERIAL NUMBER 1328-5

BLACKBODY TEMP. 500°K
F.O.V. 60°
AREA 70μm x 70μm
OPERATING TEMP. 77°K
LOAD RESISTOR 1KΩ
BANDPASS 10 Hz
SYSTEM GAIN 8.5×10^5

ELE. No.	E_{oc} (mv)	I_{det} (ma)	Responsivity λ V/W	R_c	R_c Cold	Detector Bias (V)	V Signal (ma)	V Noise (ma)	S/N	D* BB (cm Hz$^{1/2}$ watt^{-1})	D* λ (cm Hz$^{1/2}$ watt^{-1})
1		0		23Ω	48Ω						
		.5	1166				440	1.8	244	6.1×10^9	1.22×10^{10}
		1.0	2174				820	2.0	410	1.02×10^{10}	2.05×10^{10}
		1.5	3182				1200	2.6	461	1.15×10^{10}	2.30×10^{10}
		2.0	4508				1700	3.2	531	1.33×10^{10}	2.65×10^{10}
		2.5	5568				2100	3.6	583	1.46×10^{10}	2.91×10^{10}
		3.0	6762				2550	4.0	637	1.59×10^{10}	3.18×10^{10}
		4.0	8486				3200	5.6	571	1.43×10^{10}	2.85×10^{10}
		5.0	10076				3800	6.0	633	1.58×10^{10}	3.16×10^{10}
		6.0	11402				4300	8.0	537	1.34×10^{10}	2.68×10^{10}

Dewar Dwell Time @ 77°K 8.5 hrs.

SPECTRAL RESPONSE vs. WAVELENGTH SERIAL NUMBER 132?-5



WAVELENGTH (MICRONS)

OPTOELECTRONICS, INC.
1309 Dynamic Street - Petaluma, Ca. 94952

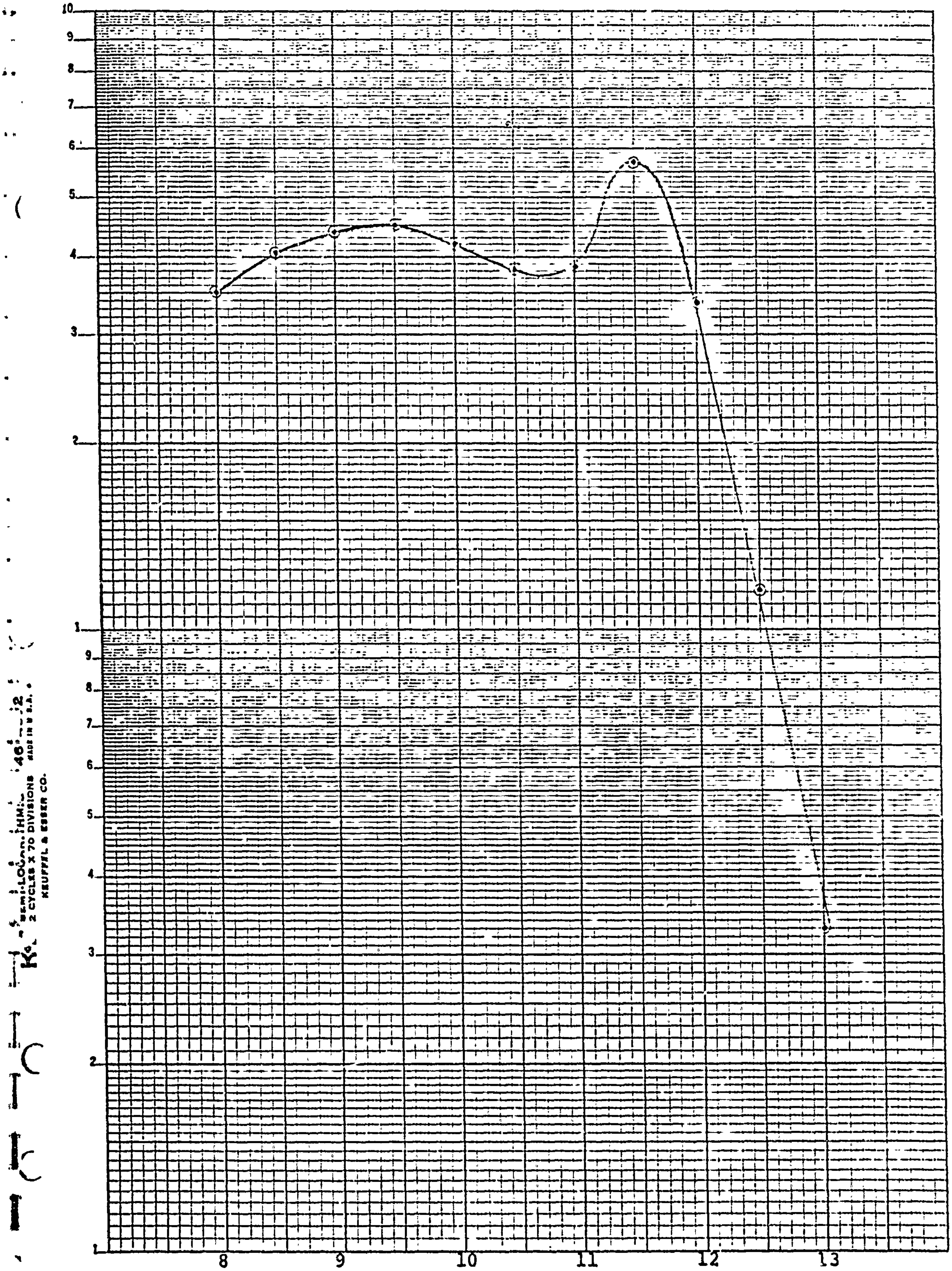
DATA SHEET

PROJECT NO. 1328
DEVICE NO. 224-UNC
DATE 4/26/72
MATERIAL HCT
TESTER W.R.S.
FLUX DENSITY 1.81064×10^{-5} w/cm^2
CHOPPING FREQ. 1K Hz
SERIAL NUMBER 1328-6

BLACKBODY TEMP. 500°K
F.O.V. 60°
AREA 70µm x 70µm
OPERATING TEMP. 77°K
LOAD RESISTOR 1KΩ
BANDPASS 10 Hz
SYSTEM GAIN 8.5×10^5

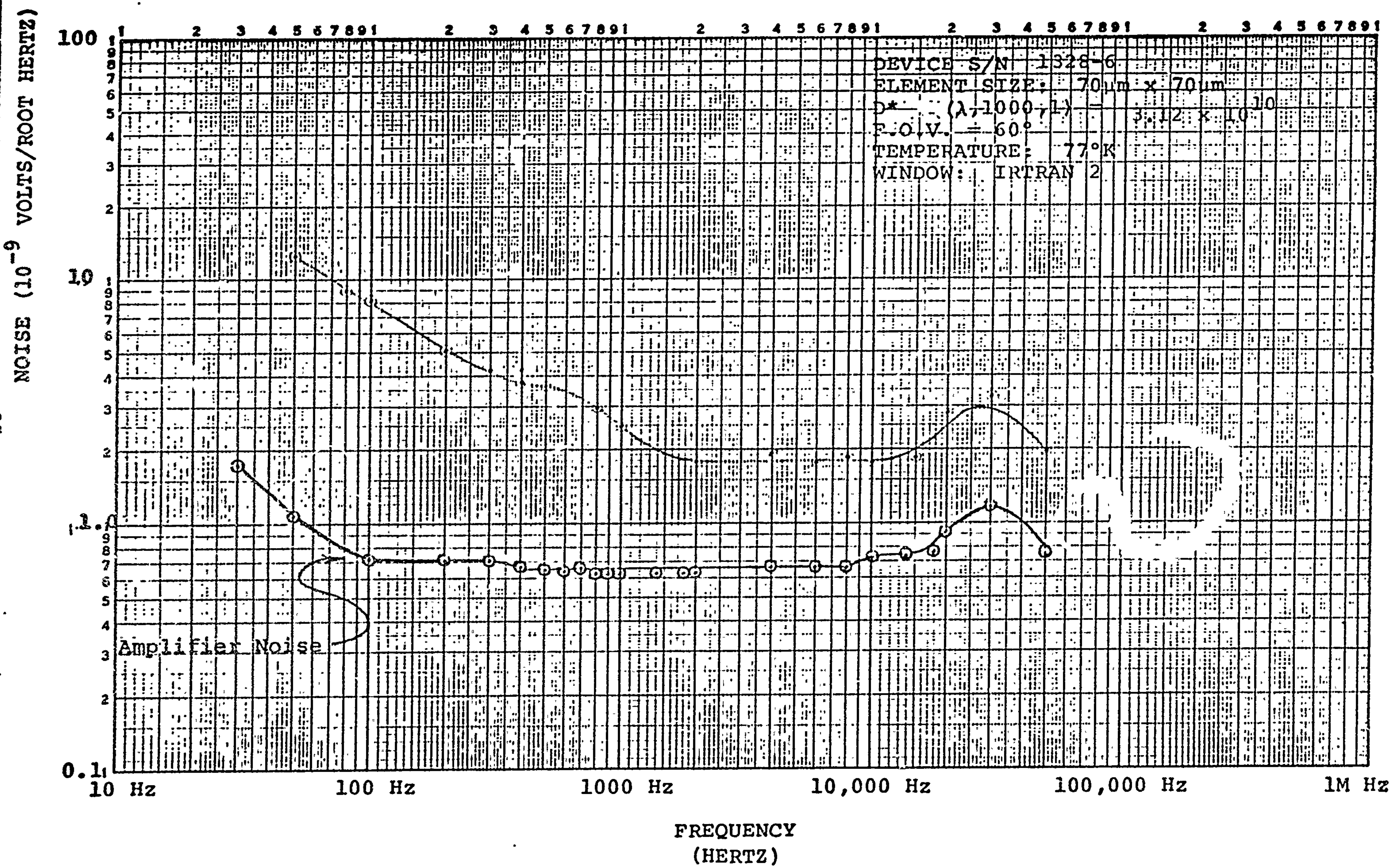
ELE. No.	E_{oc} (mv)	I_{det} (ma)	Responsivity λ (V/W)	R_c Amb	R_c Cold	Detector Bias (V)	V Signal (mv)	V Noise (mv)	S/N	(cm Hz$^{1/2}$ watt^{-1}) D* BB	D* λ
Single		0		29Ω	38Ω			1.8			
		1.0	1882				710	2.2	323	8.05×10^9	1.61×10^{10}
		1.5	2784				1050	2.4	438	1.09×10^{10}	2.18×10^{10}
		2.0	3712				1400	2.8	500	1.25×10^{10}	2.50×10^{10}
		3.0	5304				2000	3.2	625	1.56×10^{10}	3.12×10^{10}
		4.0	6702				2550	4.0	638	1.59×10^{10}	3.18×10^{10}
		5.0	7956				3000	5.0	600	1.50×10^{10}	3.00×10^{10}
		6.0	9016				3400	6.0	567	1.41×10^{10}	2.82×10^{10}

Dewar Dwell Time @ 77°K 8.5 hrs.



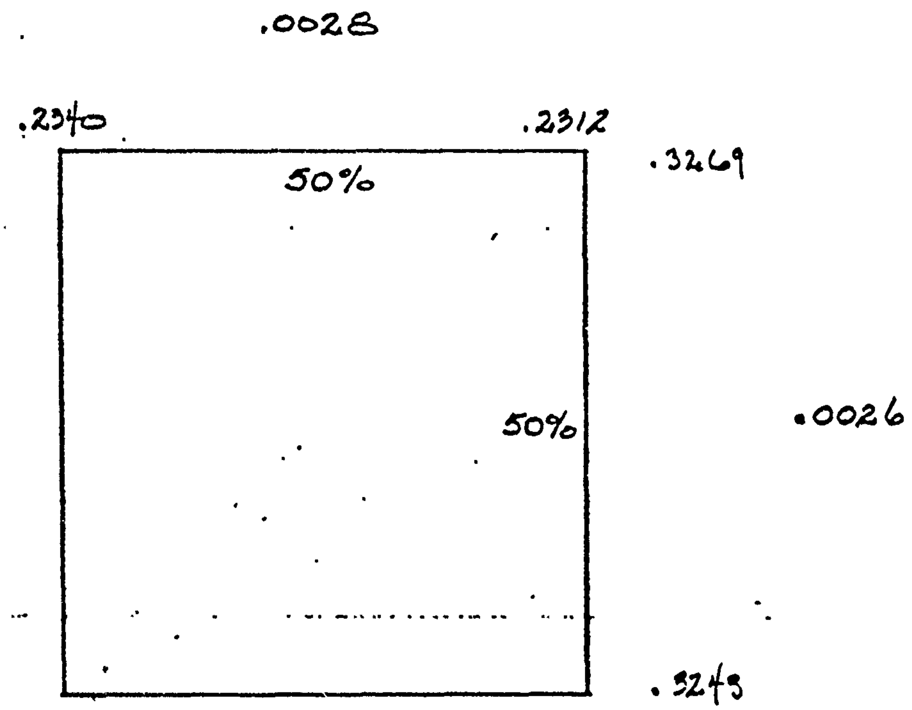
WAVELENGTH (MICRONS)

OPTO/MULLARD CMT NOISE SPECTRUM
FINAL PACKAGE



OPTOELECTRONICS, INC.

SK



PROJECT # 1328	W/O #	TOL. .00 ±.015	TITLE Spot Contour
MATERIAL		.000 ±.010	OPTOELECTRONICS, INC.
DESIGNER	DATE	APPROVED	SK

OPTOELECTRONICS, INC.
1309 Dynamic Street - Petaluma, Ca. 94952

DATA SHEET

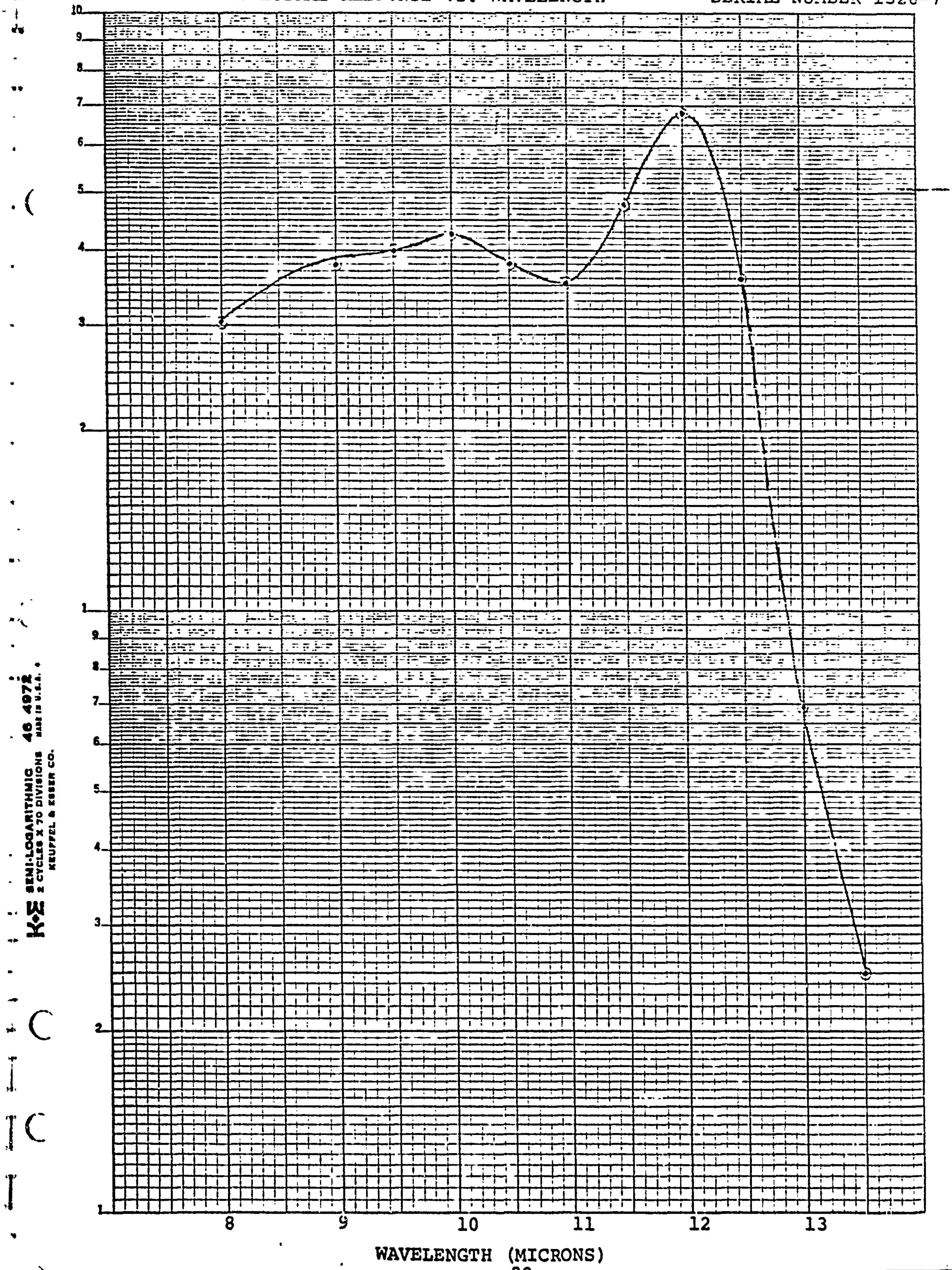
PROJECT NO. 1328
DEVICE NO. 225-UNC
DATE 3/20/72
MATERIAL HCT
TESTER EA--RM
FLUX DENSITY 6.22409×10^{-6} w/cm^2
CHOPPING FREQ. 1K Hz
SERIAL NUMBER 1328-7

BLACKBODY TEMP. 500°K
F.O.V. 60°
AREA 70μm x 70μm
OPERATING TEMP. 77°K
LOAD RESISTOR 1KΩ
BANDPASS 10 Hz
SYSTEM GAIN 8.5×10^5

ELE. No.	E_{oc} (mv)	I_{det} (ma)	Responsivity λ V/W	R_c Amb	R_c Cold	Detector Bias ( )	V Signal (mv)	V Noise (mv)	S/N	(cm Hz$^{1/2}$ watt^{-1}) D* BB	D* λ
Single		0		28Ω	34Ω			1.8			
		.5	2346				330	2.4	138	9.98×10^9	1.99×10^{10}
		1.0	4784				620	3.0	207	1.50×10^{10}	3.00×10^{10}
		1.5	6944				900	3.6	250	1.81×10^{10}	3.63×10^{10}
		2.0	9066				1175	4.0	294	2.13×10^{10}	4.26×10^{10}
		2.5	10994				1425	5.0	285	2.07×10^{10}	4.14×10^{10}
		3.0	12730				1650	6.5	254	1.84×10^{10}	3.68×10^{10}
		4.0	16200				2100	8.0	263	1.91×10^{10}	3.81×10^{10}
		5.0	18900				2450	9.0	272	1.98×10^{10}	3.95×10^{10}

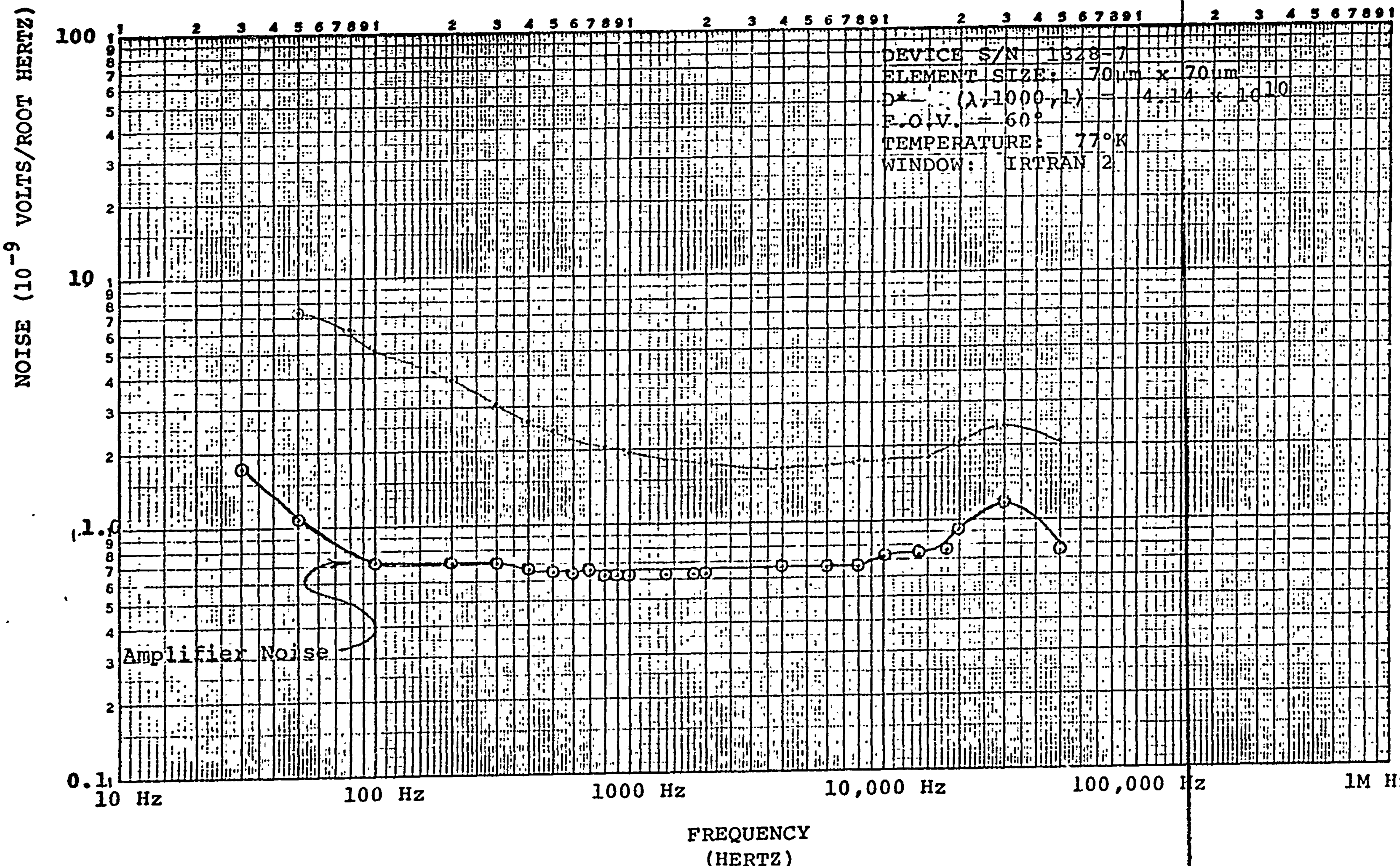
Dewar Dwell Time @77°K 8.5 hrs.

SPECTRAL RESPONSE vs. WAVELENGTH SERIAL NUMBER 1328-7

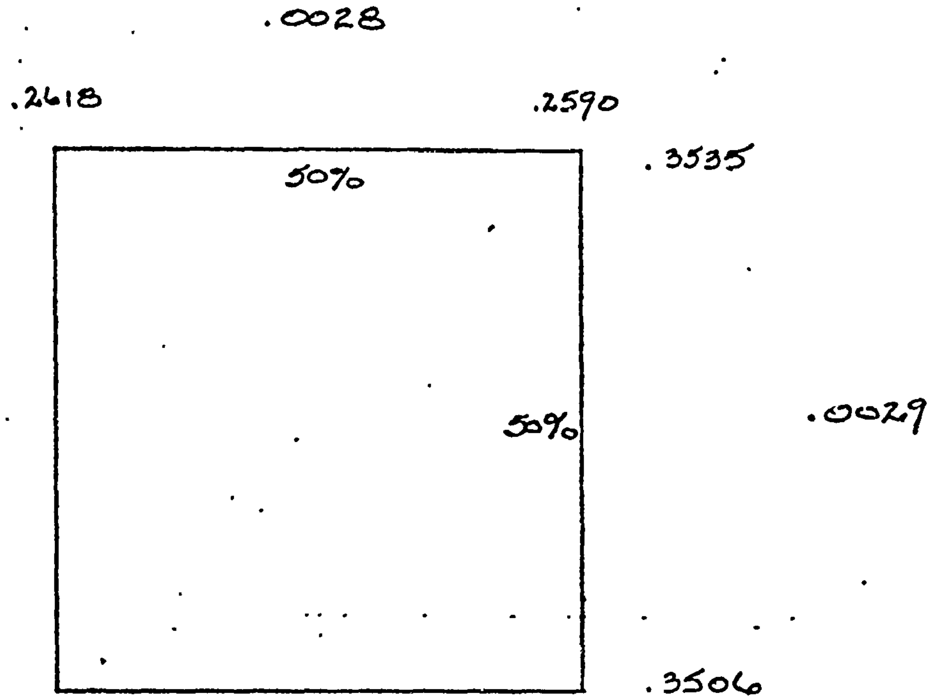


KEUFFEL & ESSER CO.

OPTO/MULLARD CMT NOISE SPECTRUM
FINAL PACKAGE



SK



PROJECT # 1328	W/O #	TOL. .00 ±.015	TITLE [illegible] CONTOUR
MATERIAL HCT		.000 ±.010	OPTOELECTRONICS, INC.
DESIGNER	DATE 3/24	APPROVED [illegible]	SK 1328-7

OPTOELECTRONICS, INC.
1309 Dynamic Street - Petaluma, Ca. 94952

DATA SHEET

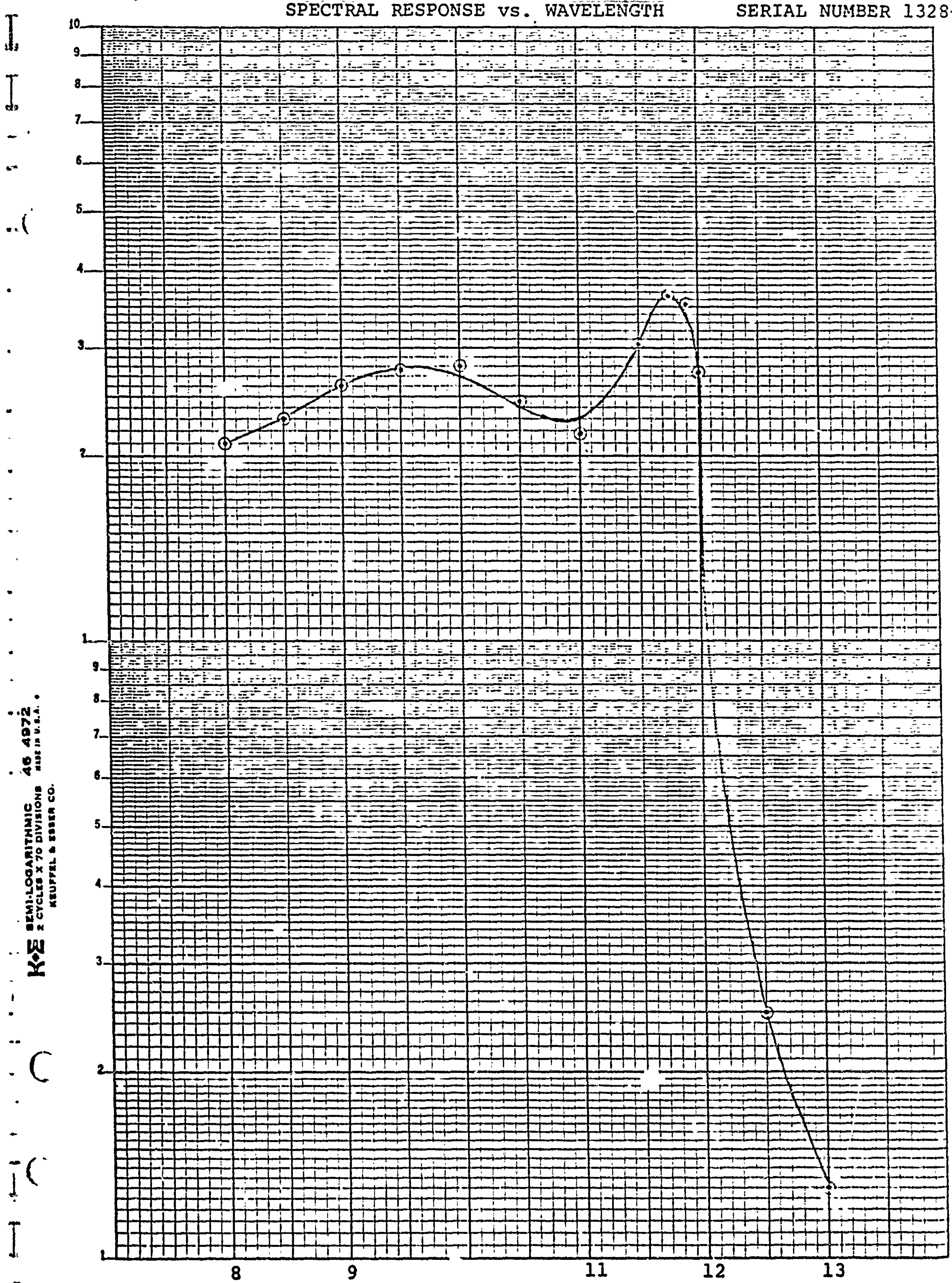
PROJECT NO. 1328
DEVICE NO. 226-UNC
DATE 3/20/72
MATERIAL HCT
TESTER EA--RM
FLUX DENSITY 6.22409×10^{-6} w/cm^2
CHOPPING FREQ. 1K Hz
SERIAL NUMBER 1328-8

BLACKBODY TEMP. 500°K
F.O.V. 60°
AREA 70μm x 70μm
OPERATING TEMP. 77°K
LOAD RESISTOR 1KΩ
BANDPASS 10 Hz
SYSTEM GAIN 8.5×10^5

ELE. No.	E_{oc} (mv)	I_{det} (ma)	Responsivity λ V/W	R_c Amb	R_c Cold	Detector Bias ( )	V Signal (mv)	V Noise (mv)	S/N	(cm Hz^{½} watt^{-1}) D* BB	D* λ
Single		0		31Ω	38Ω			1.8			
		.5	2160				280	2.2	127	9.24×10^{9}	1.85×10^{10}
		1.0	4088				530	3.0	177	1.28×10^{10}	2.56×10^{10}
		1.5	5862				760	3.6	211	1.53×10^{10}	3.06×10^{10}
		2.0	7716				1000	4.2	228	1.73×10^{10}	3.46×10^{10}
		2.5	9258				1200	4.7	255	1.85×10^{10}	3.71×10^{10}
		3.0	10608				1375	5.2	264	1.92×10^{10}	3.84×10^{10}
		4.0	12150				1575	7.5	210	1.52×10^{10}	3.05×10^{10}
		5.0	14658				1900	9.0	211	1.53×10^{10}	3.06×10^{10}

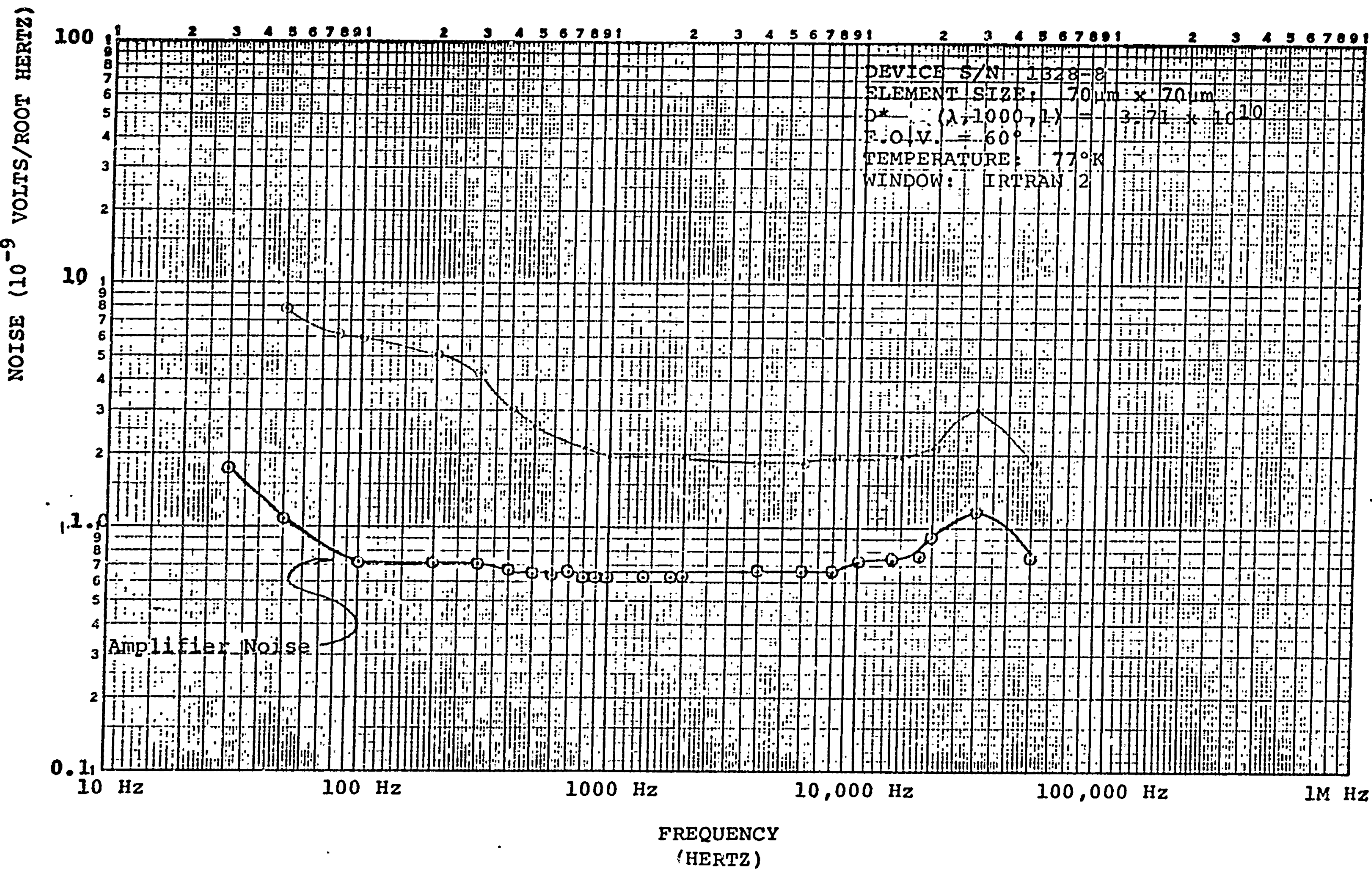
Dewar Dwell Time @ 77°K 8.5 hrs.

SPECTRAL RESPONSE vs. WAVELENGTH SERIAL NUMBER 1328-

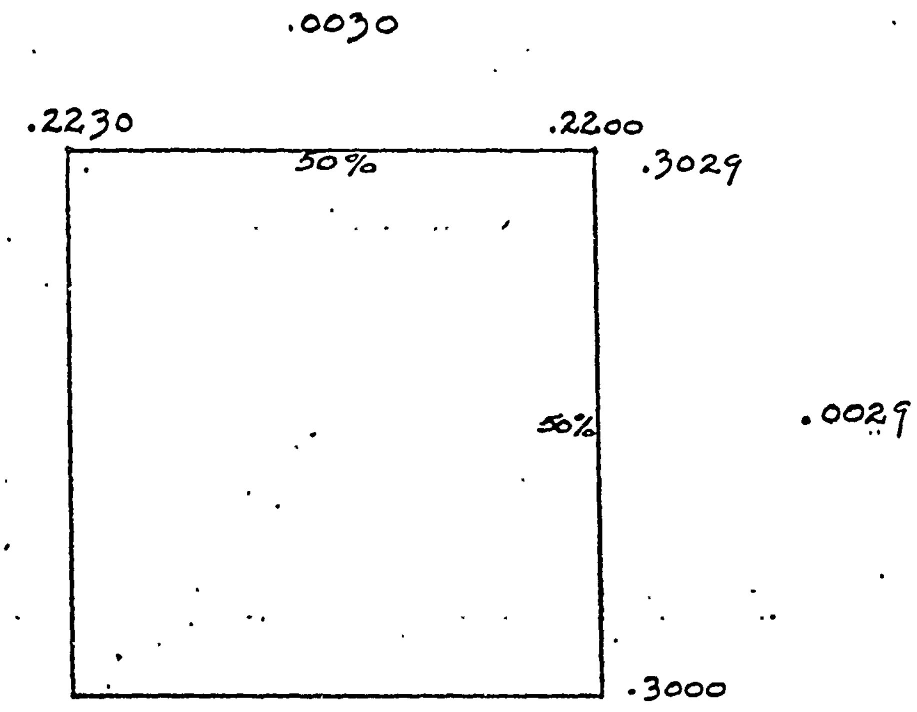


WAVELENGTH (MICRONS)

OPTO/MULLARD CMT NOISE SPECTRUM
FINAL PACKAGE



SK



PROJECT # 1328	W/O #	TOL. .00 ±.015	TITLE Spot Contour
MATERIAL HCT		.000 ±.010	OPTOELECTRONICS, INC.
DESIGNER	DATE 5/24	APPROVED	SK 1328-3

OPTOELECTRONICS, INC.
1309 Dynamic Street - Petaluma, Ca. 94952

DATA SHEET

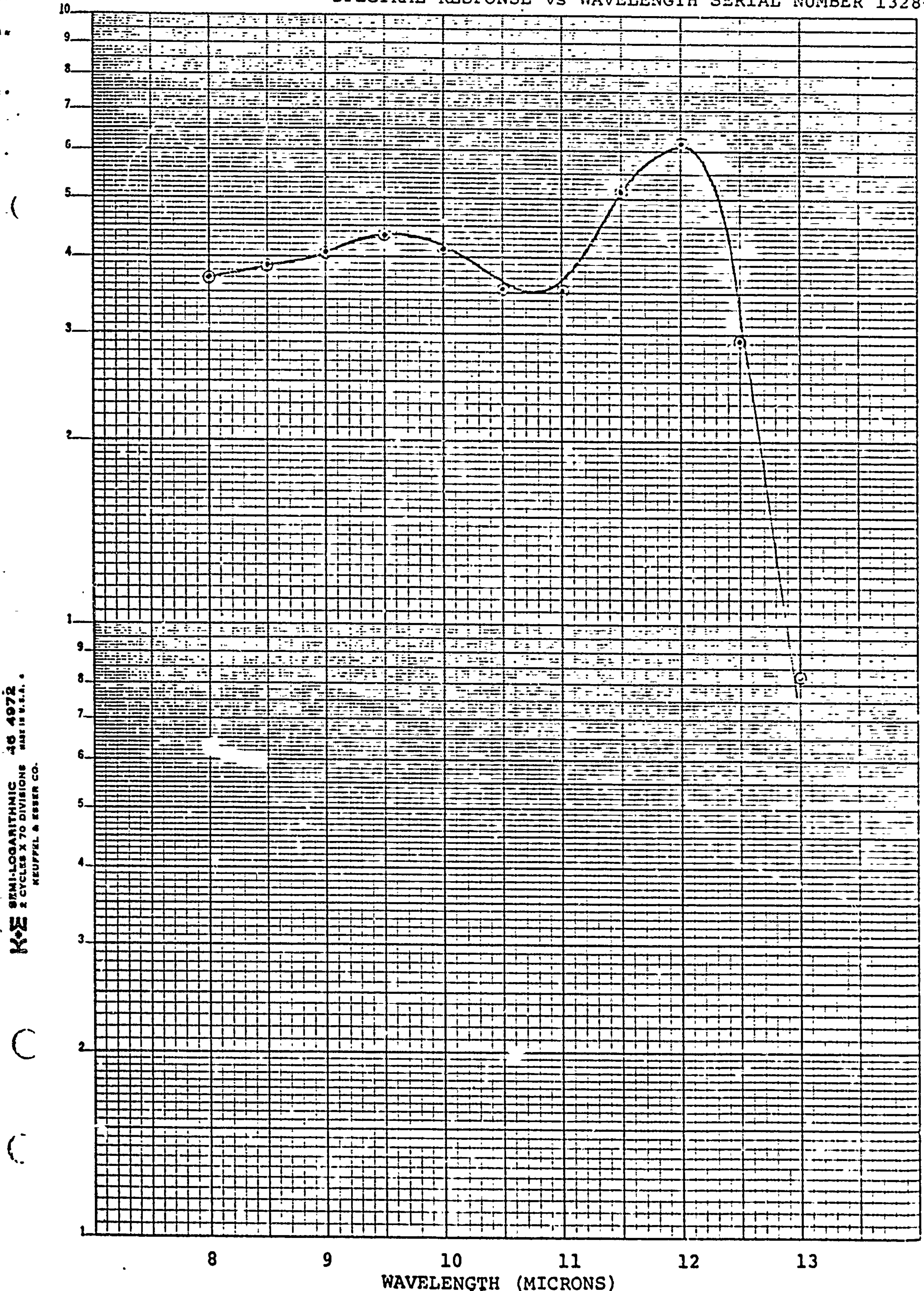
PROJECT NO. 1328
DEVICE NO. 227-UNC
DATE 3/20/72
MATERIAL HCT
TESTER EA--RM
FLUX DENSITY 6.22409×10^{-6} w/cm^2
CHOPPING FREQ. 1K Hz
SERIAL NUMBER 1328-9

BLACKBODY TEMP. 500°K
F.O.V. 60°
AREA 70μm x 70μm
OPERATING TEMP. 77°K
LOAD RESISTOR 1KΩ
BANDPASS 10 Hz
SYSTEM GAIN 8.5×10^5

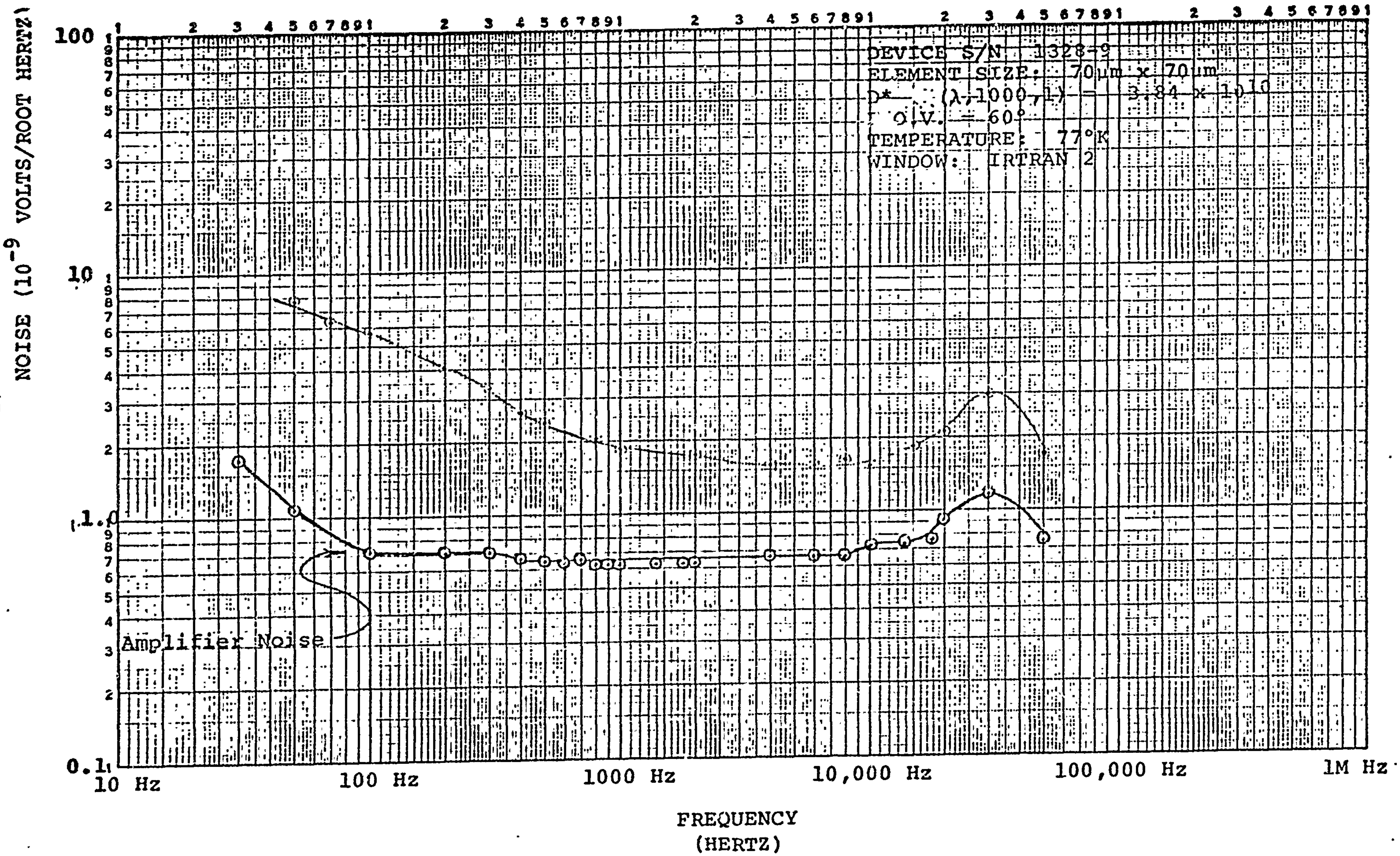
ELE. No.	E_{oc} (mv)	I_{det} (ma)	Responsivity λ V/W	R_c Amb	R_c Cold	Detector Bias ( )	V Signal (mv)	V Noise (mv)	S/N	D* BB (cm Hz^{½} watt^{-1})	D* λ (cm Hz^{½} watt^{-1})
Single		0		28Ω	35Ω			1.5			
		.5	1850				240	1.7	141	1.02×10^{10}	2.04×10^{10}
		1.0	3616				430	2.2	195	1.42×10^{10}	2.84×10^{10}
		1.5	4784				620	2.8	221	1.61×10^{10}	3.22×10^{10}
		2.0	6404				830	3.4	244	1.77×10^{10}	3.54×10^{10}
		2.5	8100				1050	3.8	276	2.01×10^{10}	4.02×10^{10}
		3.0	9258				1200	4.5	267	1.94×10^{10}	3.88×10^{10}
		4.0	13150				1575	5.6	281	2.04×10^{10}	4.08×10^{10}
		5.0	14466				1875	7.0	268	1.94×10^{10}	3.89×10^{10}

Dewar Dwell Time @ 77°K 8.5 hrs.

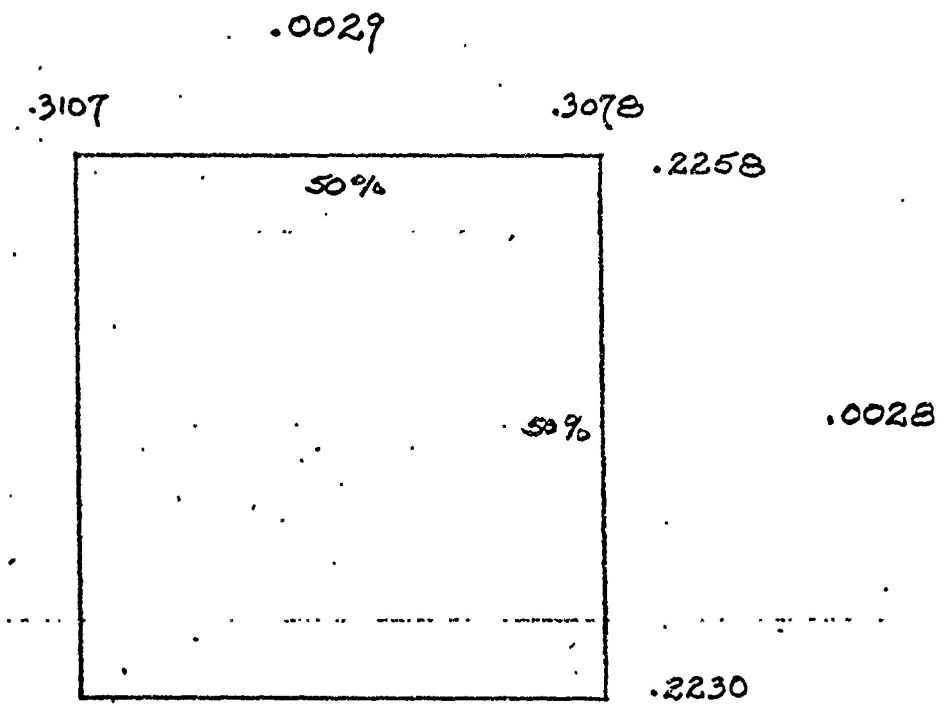
SPECTRAL RESPONSE vs WAVELENGTH SERIAL NUMBER 1328-9



OPTO/MULLARD CMT NOISE SPECTRUM
FINAL PACKAGE



SK



PROJECT # 1223	W/O #	TOL. .00 ±.015	TITLE Spot Contour
MATERIAL NST		.000 ±.010	OPTOELECTRONICS, INC.
DESIGNER	DATE [illegible]	APPROVED [illegible]	SK [illegible]

OPTOELECTRONICS, INC.
1309 Dynamic Street - Petaluma, Ca. 94952

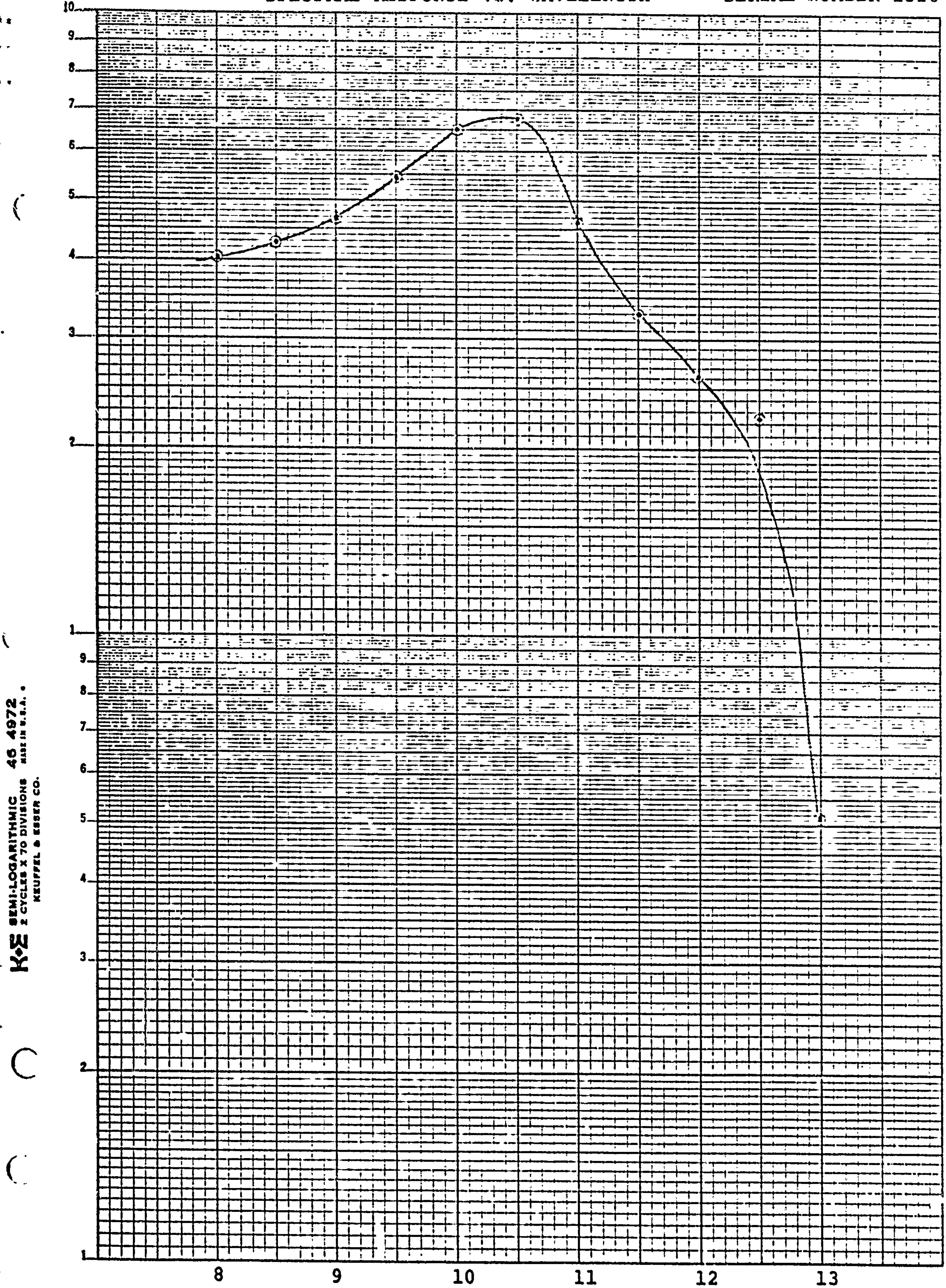
DATA SHEET

PROJECT NO. 1328
DEVICE NO. 228-UNC
DATE 3/20/72
MATERIAL HCT
TESTER EA--RM
FLUX DENSITY 6.22409×10^{-6} w/cm^2
CHOPPING FREQ. 1K Hz
SERIAL NUMBER 1328-10

BLACKBODY TEMP. 500°K
F.O.V. 60°
AREA 70μm x 70μm
OPERATING TEMP. 77°K
LOAD RESISTOR 1KΩ
BANDPASS 10 Hz
SYSTEM GAIN 8.5×10^5

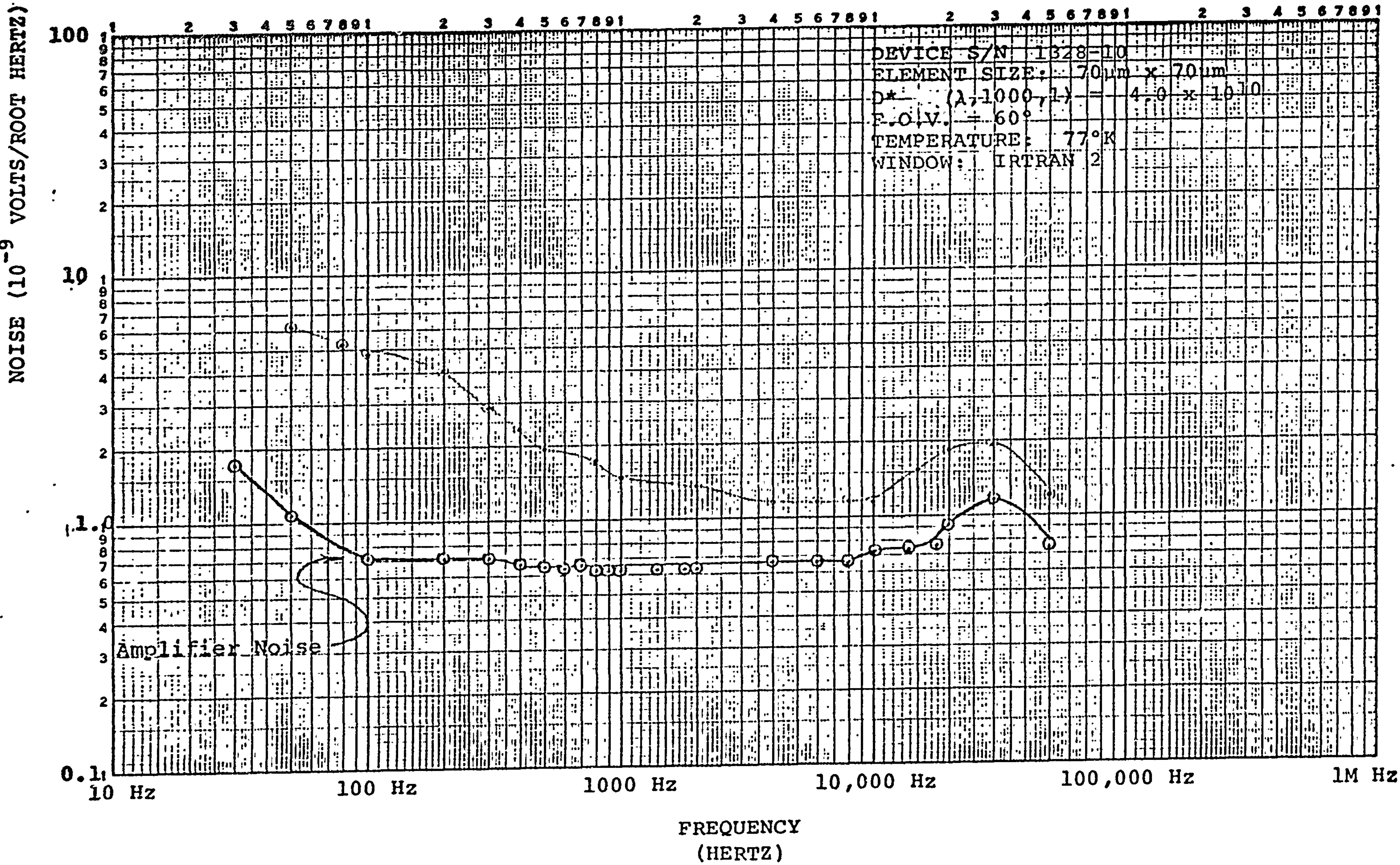
ELE. No.	E_{oc} (mv)	I_{det} (ma)	Responsivity λ V/W	R_c Amb	R_c Cold	Detector Bias ( )	V Signal (mv)	V Noise (mv)	S/N	D* BB (cm Hz$^{1/2}$ watt^{-1})	D* λ (cm Hz$^{1/2}$ watt^{-1})
Single		0		29Ω	37Ω			1.8			
		.5	2004				260	2.2	118	8.58×10^9	1.72×10^{10}
		1.0	3856				500	2.8	179	1.30×10^{10}	2.60×10^{10}
		1.5	5710				740	3.6	205	1.49×10^{10}	2.98×10^{10}
		2.0	7716				1000	4.0	250	1.81×10^{10}	3.62×10^{10}
		2.5	9258				1200	5.0	240	1.74×10^{10}	3.48×10^{10}
		3.0	10608				1375	5.0	275	2.00×10^{10}	4.00×10^{10}
		4.0	13116				1700	7.0	243	1.76×10^{10}	3.52×10^{10}
		5.0	15420				2000	8.0	250	1.81×10^{10}	3.62×10^{10}
Dewar Dwell Time			@ 77°K	8.5 hrs.							

SPECTRAL RESPONSE vs. WAVELENGTH SERIAL NUMBER 1328-10

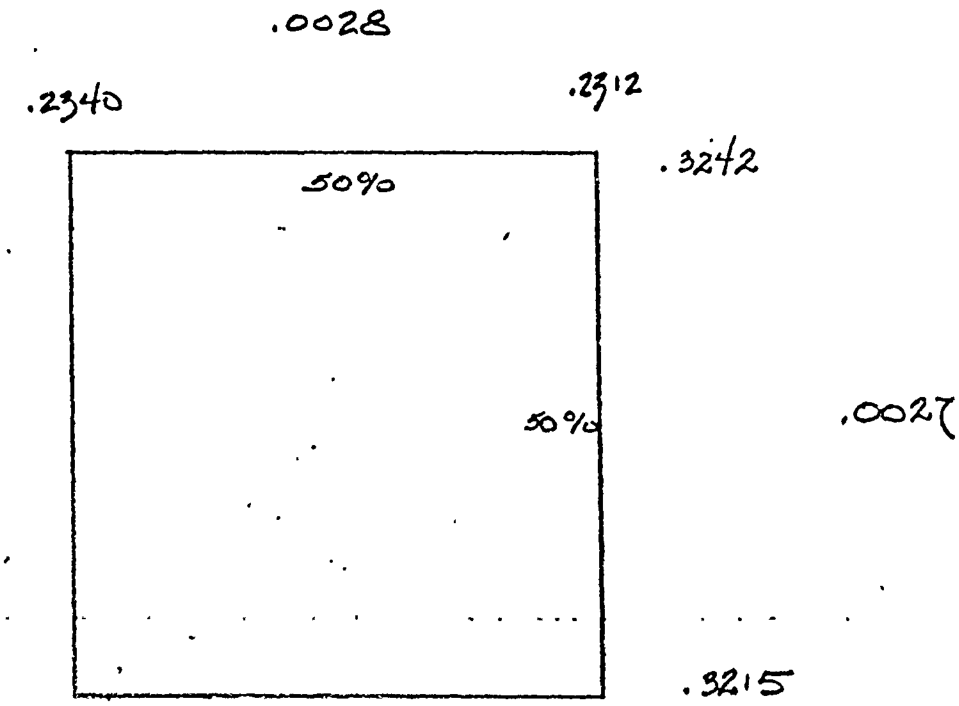


WAVELENGTH (MICRONS)

OPTO/MULLARD CMT NOISE SPECTRUM
FINAL PACKAGE



SK



PROJECT # 1328	W/O #	TOL. .00 ± .015	TITLE Spot Contour
MATERIAL HC		.000 ± .010	OPTOELECTRONICS, INC.
DESIGNER	DATE -/24	APPROVED	SK 1323-10